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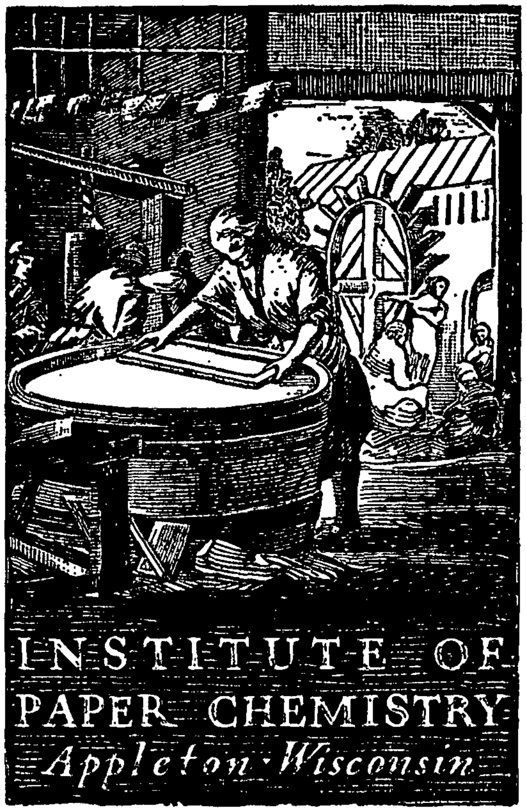

AN INSTRUMENTATION STUDY OF THE CONCORA MEDIUM FLUTER

Project 1108-11

Progress Report One

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

May 1, 1959

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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I. SUMMARY

In late 1957 and 1958 the Institute was requested to conduct a round-robin study of the Concora medium test in order to compare results obtained between laboratories. In brief, the results indicated that appreciably different test results were obtained by certain of the laboratories participating in that study. With these and other considerations in mind, the Institute was authorized to initiate an instrumentation study of the Concora test with the objective of determining mechanical or operational factors that may cause differences in test results. The results obtained in the study to this date are summarized herein.

During the course of the work, attention was focussed on the matter of flute height and its relationship to test results. Perhaps the most significant conclusions reached in the study were related to this factor and the principal findings are summarized below:

1. Significant changes in flute height occurred from day to day in specimens formed by the machine used in this study.

2. Changes in flute height appear to be reflected by changes in test value, i.e., the lower the flute height, the higher the test reading. The data of this report suggest that to maintain test results within ± 1%, average flute height should be held to about ± 2 points.

As a result of the above, the average test level may fluctuate from day to day, depending, in part, on the flute height of the specimens produced by the fluter at a given time. The extent of the fluctuations will depend on the magnitude of the changes in flute height. The variations in flute height from specimen to specimen are also believed to affect the test precision. For example, it has frequently been observed that high individual test values are usually associated with specimens of low flute height. This may have the effect of inflating the test standard deviation.

It is believed, at present, that the most logical explanation for these observations lies in variations in the effective roll pressure--because of frictional effects associated with movement of the pressure roll and slider. In other words, it is suggested that the effective roll pressure may vary sufficiently from specimen to specimen and day to day as to significantly influence both flute height and test readings. These changes occur despite the fact that no adjustments in spring force were made. As a result, certain modifications in the instrument design appear to be necessary in order to reduce the fluctuations on flute height and test reading. Adjustments in machine test level can be effected by changing the spring force, and this procedure may be used to bring differing fluters into agreement. However, variations in flute height and test readings from specimen to specimen or day to day may not be effectively controlled by this procedure.

Basically, it is believed that the Concora fluter has been a useful instrument in the evaluation of corrugating medium. However, the above results have suggested that if improvements could be made in the fluter itself, that would reduce differences and changes in flute height, a better instrument would result. These and other findings have been relayed to the manufacturer together with certain suggestions as to methods of improvement. Other and more efficient methods may occur to the manufacturer.

The above summarizes certain important features of the results and the above conclusions have been based on several phases of the experimental work including a rather extensive analysis of the performance of the Institute's fluter over several months. The following summarizes results obtained in other phases of the instrumentation study:

1. Effect of spring pressure

A recheck of the previous work on the effect of spring pressure was performed. The results appeared to be in qualitative agreement with previous results--that is, lowering the spring pressure tends to decrease flute height and increase Concora flat crush.

2. Effect of blocked pressure roll

To simulate, in part, the effect of a sticking roll or slider, the movement of the rolls was artificially restricted. When the rolls were free to separate only a short distance, somewhat lower results were obtained although the change was not great. When the rolls were blocked in such a manner that they could not completely mesh, higher Concora flat crush tended to occur.

3. Effect of specimen width

The effect of specimen width was studied primarily because it offered a secondary comparison of the effect of roll pressure. Thus, as the specimen width is reduced, the effective roll pressure should increase in direct proportion. The assumption must be made, however, that test readings will be directly proportional to specimen width. With this in mind, decreasing the specimen width increased flute height and decreased test results.

4. Effect of tilting or cocking the drive roll

In an effort to simulate the effect of uneven pressures across the specimen width such as might be caused by a warped hot plate, the drive roll was tilted slightly. For the small degree of cocking used, little or no change in either flat crush or pressure pattern was observed.

5. Effect of roll temperature

This factor was reinvestigated in this study and appeared to have even less effect on test readings--within a range from 300 to 400°F.--than was observed in the original instrumentation study.

6. Effect of a difference in roll temperature on Concora results

The effect of a 50°F. difference in temperature between the two rolls was investigated. As was expected, no appreciable change in results was observed. In view of the results in Parts 11 and 12, the present ± 25°F. specification on roll temperature appears adequate.

7. Rack and Comb--Comparison of original and modified rack and comb

The manufacturer has slightly modified the design of the rack and comb used in forming the specimens by reducing the height (about 0.05 inches) of the top end surfaces of the rack. The change was apparently made in an effort to reduce the commonly observed differences in flute height between end and middle flute. A comparison of the two types of rack and comb assemblies indicated that (1) no improvement in flute height uniformity resulted, and (2) the two types of racks yielded equivalent test results.

8. Rack and Comb--Preliminary trials of meansof achieving more uniform end and center flutes

It has been observed in all phases of the study that, within a given specimen, the height of the two end flutes is usually from 10 to 20 points greater than for the middle flutes. This difference in flute height appears to arise in the taping operation. Because of the desirability of improving flute height uniformity even within a given specimen various methods of eliminating the high end flutes were discussed and a number of comparisons were made employing 8 or 6 flute specimens where the high end flutes were manually collapsed prior to test. On the basis of the results obtained, it appeared that the high end flutes may have only a minor effect, on either the test load or precision. It, therefore, suggested that principal attention might well be centered on the problem of reducing differences in flute height between specimens or machines.

9. Comparison of taping methods

During the course of the study a question arose as to the effect of differing taping methods in test results. The questions seemed to hinge on (1) the use of a rubber roller in pressing the tape to the specimen as opposed to hand pressing and (2) the method of removal of the specimen from the rack. A comparison of the two methods indicated that equivalent test results and flute heights were obtained.

10. Effect of moisture content and test atmosphere

Previous results on the effect of specimen moisture content before fluting were reviewed. While this factor may have some effect on test readings, its effect does not appear to be of major importance except, perhaps, under extreme conditions.

Additional information on the effect of test atmosphere on Concora results obtained when tested immediately after fluting was secured. The results indicated that appreciably different results might be obtained if the test atmosphere were relatively humid--a factor which might be of interest when the fluter and tester are located in an unconditioned atmosphere.

The Concora test involves three pieces of equipment--namely, the fluter, rack and comb and the compression tester. All these can, conceivably, contribute to differences in test readings. In this study, attention has been focussed on variables associated with the fluter and rack and comb. It should be kept in mind, however, that careful maintenance and calibration of the compression tester is a necessity if the results are to be meaningful.

II. INTRODUCTION

A. GENERAL

At the request of the Technical Committee of the Fourdrinier Kraft Board Institute, Inc., a round-robin study on the Concora medium test was made in late 1957 and early 1958 in order to compare results obtained between laboratories. The results obtained in that study were summarized in a report to the Fourdrinier Kraft Board Institute entitled "Investigation of Concora Medium Fluter," Project 1108, Progress Report 9, May 1, 1958. The following briefly summarizes the results obtained:

1. No given mill retained the same ranking relative to the other mills through all sample lots.
2. When the results obtained at the Institute were used as an arbitrary reference level, the test results varied on the average from +9.4% to -6.2%.
3. Eleven of the seventeen mills exhibited composite averages which were within a ± 4% range of the composite averages obtained on the I.P.C. tester. When a range of ± 2.5% was considered, seven of the seventeen mills fell within that range.

Additional samples were then forwarded to six of the mills which exhibited particularly high or low results in the first round robin. Analysis of these results indicated that three of the mills appeared to exhibit equally high results in the second study, while the remaining mills were now in closer agreement with the I.P.C. results.

Taken as a whole, the above indicated that appreciably different test results were obtained by certain of the laboratories participating in the study. Among the possible causes of such differences, the following might be included:

1. Fluter
2. Rack and comb
3. Test machine
    a. Calibration
    b. Test rate
    c. Type of test machine
4. Test atmosphere
5. Test operator

With regard to the above, it seems unlikely that differing test operators could so markedly influence the final test results when specimens are conditioned after fluting. Their efficiency might be a variable, however, when specimens are not conditioned after fluting because of the rapid changes in specimen moisture content and temperature which occur in the first few minutes after the specimen emerges from the fluter.

The effect of differing test atmosphere on conditioned Concora results would be expected to parallel flat-crush results. For example, reference 3 indicates that fluted Concora test specimens conditioned at 85% R.H. prior to test lost 43.4% flat crush on the average as compared to 50% R.H. Single-faced board samples fabricated with the same mediums lost 42.1% flat crush at

85% R.H. Therefore, using other data for the effect of humidity on flat crush it may be estimated that TAPPI tolerances of ± 2% R.H. could correspond to about a ± 1.3% change in flat crush. Rather large deviations from the TAPPI tolerances would be required, therefore, to explain the deviations encountered on the round-robin studies. It may also be remarked that the test atmosphere may be a variable in "immediate" testing. Thus, the rate of temperature and moisture change in the specimen after fluting will depend on the temperature and humidity of the test atmosphere and, as will be developed in later pages, may significantly influence test results.

The differences between laboratories noted in the two round-robin studies might also have arisen because of calibration errors or other instrumental variables associated with the H and D compression testers used by the laboratories. The strongest evidence on this score would have been a concurrent round-robin study involving evaluation of combined board flat-crush samples by the various laboratories. In lieu of such evidence, it may be noted that certain of the laboratories participating in the second round-robin study carefully checked the calibration of their compression machines prior to performing their Concora tests and observed little or no change in their Concora results.

With the foregoing considerations in mind, the Institute was authorized to initiate an instrumentation study of the Concora medium fluter with the objective of determining mechanical or operational factors that cause differences in Concora test results. The results obtained to date are summarized herein.

B. DESCRIPTION OF INSTRUMENT

The Concora medium test was first described by Long and Maltenfort in 1952 and a second paper by the same authors presented certain further considerations in 1956 (1, 2). The fluter consists of a pair of 9-inch corrugating rolls, each with 84 teeth, 3/4 inch in width. One roll is driven through a gear reducer at a speed of about 10 feet per minute. The second roll is pressed in contact with the driving roll through a slider riding in ways on the underside of the hot plate. A spring is used to apply pressure to the slider. Reference 1 indicates that pressure between rolls is intended to be 36 lb. per lineal inch. Current specifications are not known.

Heat is transferred to the rolls by means of heaters in direct contact with the under side of the plate on which the rolls ride. In the original model obtained by the Institute, four strip heaters were employed; later models employ a single rectangular heating plate with approximate dimensions of 7-3/4 x 16-1/4 inches.

With the machine at operating temperature, the 6 by 1/2 inch specimens are fed into the corrugating rolls. When the specimen emerges from the rolls it is carefully transferred to a corrugated rack where it is held in shape by means of a comb while pressure-sensitive tape simulating the single-face liner is adhered to the flute tips. The comb is then slipped out of the flute tips, the specimen lifted out of the rack and its flat-crush strength determined.

C. REVIEW OF PREVIOUS INSTRUMENTATION STUDIES

As indicated above, Concora results are obtained after subjecting specimens to a sequence of events, involving fluting, taping, and compression testing. With regard to the compression tester, the H. and D. compression machine is generally used in testing Concora specimens. The machine has bee in use in the industry for many years and, if proper attention is given to certain variables, has proved to be generally reliable. While differences in Concora results can certainly arise from differences in compression testers, it was felt that, in view of the above, attention should be centered in the initial phases of the instrumentation study on the fluter and rack and comb.

Considering the fluter, there are two apparent primary variables--both of which were investigated in a previous instrumentation study (3). They are temperature and pressure. With regard to temperature, the previous study indicated that Concora readings tended to increase with temperature; however, the effect was small. Over a range of 265°F. (149°F. to 414°F.), Concora results changed from 47.93 lb. to 57.05 lb. or about 0.034 pounds per°F. For the 50°F. range encompassed in the present ± 25°F. tolerance on temperature, the temperature effect would amount to about ± 0.5 p.s.i. (Note: A recheck of the effect of temperature in this study indicated that roll temperature may have even a lesser effect near the normal operating range.) Temperature control has usually not been difficult to maintain, although uneven roll temperatures may be a problem at times. The effect of uneven temperature was not investigated in the previous study; however, within the stated tolerance limits no great effect would be expected. Uneven temperatures may be obtained in a number of ways and the results of one experimental procedure are reported herein.

Pressure may superficially be controlled by adjustment of the spring holding the driven roll in contact with the driving roll. Without changing the adjustment of the spring, frequent observations have indicated that the actual force may vary within wide limits and appears to depend upon such factors as the state of the lubricant and the condition of the sliding surfaces. For example, rust and corrosion of the surfaces on the slider have been observed to markedly increase the actual force holding the surfaces together. In other words, frictional forces tend to resist movement of the slide and roll and may contribute significantly to the effective force between rolls. It may be kept in mind that such frictional forces act to oppose movement; that is, when the rolls are moved apart, frictional forces add to the pressure exerted by the spring; the converse occurs when the rolls are attempting to move or are being moved together. A second and more subtle difference occurs at times. With all factors in an apparently normal state, the pressure roll may be drawn smoothly away from the driving roll. At other times when, for example, corrosion interferes with the free action of the slider, a relatively high force is required to initiate separation of the rolls followed by a drop in force to more normal values as the separation increases. Among the secondary factors which may affect the pressure are the following:

a. spring pressure

b. lubricant

c. sticking slider

d. sticking roll

e. roll wear on hot plate

f. hot plate warping

g. type of plating on sliding surfaces

Most of the above are difficult items to define and study in order that their effect on Concora readings may be assessed. However, it is probable that the above may include certain variables which have a substantial effect on results.

With the above in mind, it may be noted that changes in the effective pressure between rolls produce two effects--a change in test readings and a change in fluted caliper. For example, in the previous instrumentation study, the following average changes were observed (3).

	Spring Force		
	10 lb.	21 lb.	40 lb.
Concora test, lb.	57.28	53.16	52.22
Caliper, points	178.6	191.1	192.6

As may be noted, lowering the spring force from 21 to 10 lb. was associated with about an 8% increase in test results and a 7% decrease in flute height. Increasing the spring force from 21 to 40 lb. decreased Concora test results by about 1.8% while caliper increased about 0.8%.

Changes in flute height may be expected to influence Concora test results--at least under some conditions--if the flute sidewalls tend to behave as columns during the latter stages of the crush test. Under these circumstances, the lower the column height, the greater the load sustained by the column.

Other machine variables investigated in the original instrumentation study included roll speed and the uniformity of the fluted rolls. Neither apparently produced a great effect in Concora test results.

In discussing the effect of moisture content on test readings, a number of possibilities may be considered. They are

1. Initial moisture content of specimen prior to fluting
2. Test atmosphere (relative humidity)
3. Time between fluting and test

With regard to the moisture content of the specimen prior to fluting, it has been found that this factor exercises a slight effect if any on Concora readings. In Reference 3, a slight increase in Concora test results was found when the prefluting moisture content of the specimens were high. A later investigation of this factor confirmed the fact that the effect was small, although the trend of the results was in the opposite direction, i.e., high initial moisture contents tended to produce lower Concora results.

As noted in Reference 4, the Concora specimen is both hot and dry as it emerges from the fluter. At once, the specimen begins to cool and to take on moisture. The rate at which the changes occur will be dependent on the test atmosphere and the greatest changes occur in the first few minutes after fluting. This means that when specimens are tested "immediately" after fluting, the test action occurs during the period in which the specimen is undergoing the most rapid changes in moisture content. Therefore, any differences in test time due to the relative efficiency of the test operators, speed of the test machine, or other factors may be expected to affect the test readings. Differences in test atmosphere may also be expected to affect test readings under these conditions also. Holding all other factors constant, specimens exposed to high humidity test atmospheres will pick up moisture at a faster rate than in a dry atmosphere. Lower readings will therefore be obtained in the high humidity test atmosphere even though the time required to test is relatively short.

III. MATERIALS

For this study, three samples of 26-lb. semichemical corrugating medium were selected at random from inventory. These samples are identified in this report by the numbers 1894, 1897, and 1898. In addition, a few comparisons of the two Concora instruments and all Control Chart comparisons were made using the sample of 26-lb. corrugating medium which is employed in the Institute's regular monthly calibration program. This sample is identified in this report as sample No. 789.

All materials used in this study were preconditioned at less than 35% relative humidity and 73 ± 3.5°F. for at least 24 hours. They were then conditioned for at least 48 hours at 50 ± 2% relative humidity and 73 ± 3.5°F. prior to use. After fluting, all specimens were conditioned at least 15 and no longer than 45 minutes at 50% R.H. and 73°F. prior to testing. Exceptions to the above are specifically noted in the text.

IV. INSTRUMENTS

The instrument supplied by the Liberty Engineering Company bears the serial number 316. The serial number of the Institute's instrument is 210. All testing was performed on a National Forge compression machine, except where specifically noted.

In addition to the above, a special caliper was constructed to facilitate measurement of flute height. As shown in Figure 1, it basically consisted of a dial gage having 0.0005-inch graduations and a flat rectangular foot about 0.5 by 0.6 inches. Early measurements using the device were made with an 82.6-gram weight attached to the top of the spindle. In later portions of the study, e.g., wherein narrow width specimens were being investigated, this pressure was excessive and it was found that satisfactory values were obtained using no added weight on the spindle.

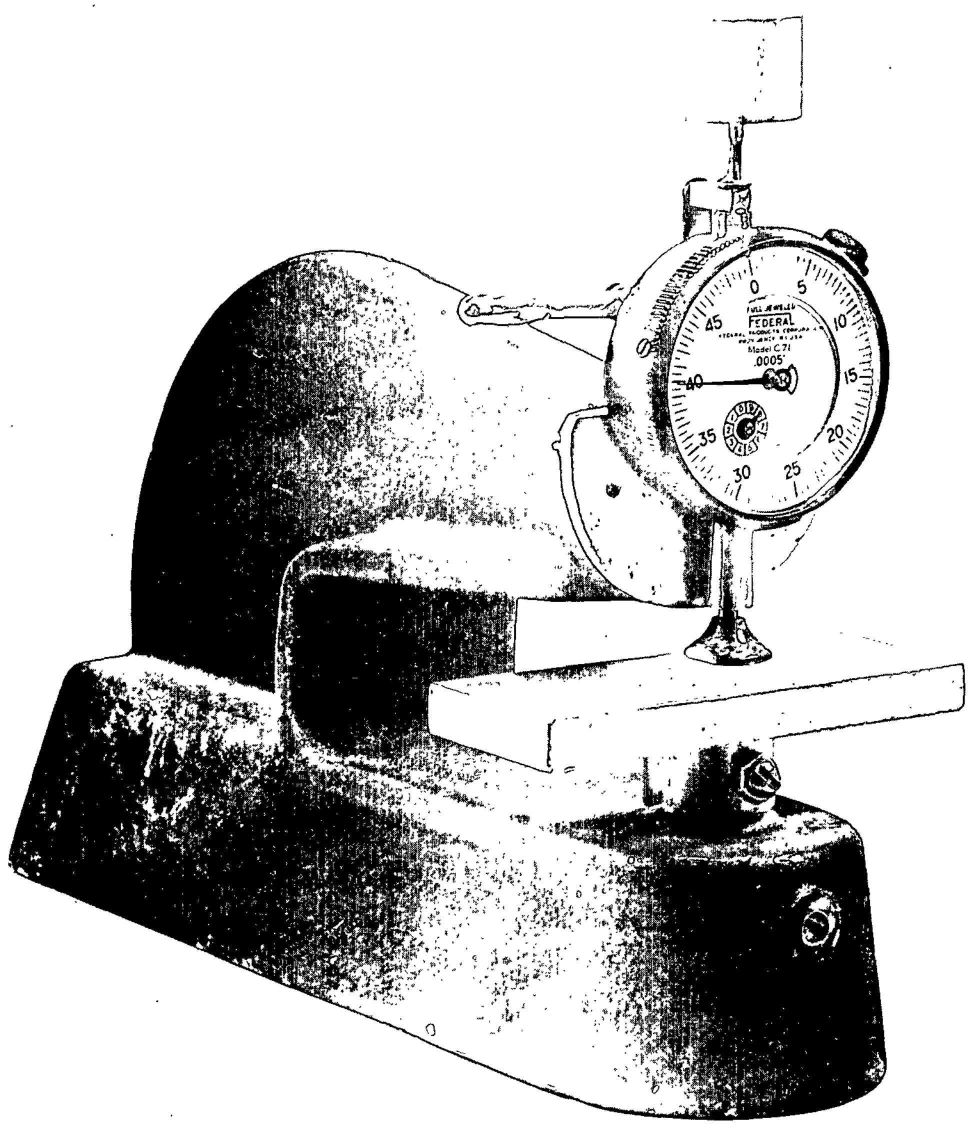


Figure 1

Special Caliper Used in Measuring Flute Height

V. TESTING PROCEDURE

For all phases of the work, 20 specimens per sample were evaluated, using one of two procedures as seemed appropriate. Thus, in Procedure 1, 10 specimens per sample were evaluated at each level of the variable studied. After completion, duplicate tests were performed using a second set of 10 specimens per sample. When this procedure was employed, the results of each trial are reported together with the average for the two trials. In the second procedure, alternate or consecutive specimens were evaluated for each condition or level of the variable studied. Any changes in fluter, test machine or test atmosphere during the test period would, therefore, not confound the comparisons.

The second procedure was preferred because of the greater protection against extraneous effects it offered; however, in some instances, it was impractical to use. For those situations, Procedure 1 was employed.

CONVERSION OF TEST VALUES

All values reported herein, with one exception, have been converted from pounds to pounds per square inch on the basis of nominal specimen area in accordance with current F.K.B.I. procedure. For normal, 10--flute specimens, the conversion is accomplished by dividing the test value in pounds by the nominal area of 1-2/3 square inches.

The exception occurs in the case of the central chart analyses reported herein. Institute control chart procedures for this instrument were set up on the basis of test readings in pounds before the procedure noted above was placed in effect.

VI. DISCUSSION OF RESULTS

PART 1. GENERAL

To place the more formal phases of the instrumentation study in proper perspective, the first two sections (Parts 2 and 3) of this report discuss (1) the initial examination of the Concora fluter submitted by the manufacturer for this study, and (2) a control chart analysis of the performance of the Institute's fluter. It is believed that the latter may be particularly valuable because of the insight it gives into the apparently interrelated factors of flute height and test reading. Following the control chart analyses, Parts 4, 5, and 6 discuss three related subjects which were investigated in connection with the control chart work. Part 5 discusses certain observations regarding slider wear; Part 6 discusses depth measurements on roll and rack in relation to specimen flute height and Part 7 briefly discusses a method for measuring leaning flutes.

The effect of roll pressure is then discussed from a number of standpoints in Parts 8 through 10 while the effects of roll temperature are summarized in Parts 11 and 12. Parts 13 through 15 deal with various aspects of the rack and comb or taping operations and, in Part 16, the general effects of moisture content are discussed.

PART 2. INITIAL EXAMINATION OF CONCORA FLUTER NO. 316

It is understood that the machine submitted by the manufacturer for this study was a unit used as a replacement for instruments returned for service. As such, it had probably received considerably more severe treatment than the normal instrument. In any event, when first received, it was impossible to obtain fluted specimens as cutting of the specimens invariably occurred. Spring force measurements indicated that a force in excess of 30 lb. (maximum scale reading of the spring scale used) was required to move the pressure roll.

When the machine was disassembled, it was observed that

1. The hot plate surface was scored and worn and that the chrome plating had flaked or worn off in various locations.

2. The hot plate surface was warped or dished--predominantly in the long direction of the plate--with the center slightly lower than the outer edges.

3. The slider and associated surfaces were pitted with rust. The slider was freed up, polished and relubricated. The machine was then reassembled and fresh lubricant (Molykote) was placed between the rolls and hot plate.

With the machine in the above condition, 20 specimens of Sample 789 were tested, giving an average of 70.2 lb. On the Institute's fluter, the long-time average for this material is 60.12 lb. with two standard error limits of 58.11 and 62.12 lb. Thus, the above indicated that No. 316 was yielding an extremely high test average. Measurements of the spring force before the specimens were fluted gave values near 17 lb.; however, measurements taken after the above specimens were tested ranged near 27 lb.

The machine was again disassembled, relubricated and restored to operating condition. No further suspicious conditions were noted except that the bearing in the drive roll was observed to be binding. This was corrected before assembly. Abnormally high spring pressures near 30 lb. continued to be obtained; however, a second check of the machine using Sample 789 was made. The average of the 20 specimens was 64.9 lb.--still well above the desired average value of 60.12 or the maximum allowable upper limit of 62.12 lb.

At this point it was thought desirable to resurface the hot plate in order to obtain a plane smooth surface for the rolls to slide on. Neither the ground surface or slide and associated parts were chrome plated; however, in retrospect, this might have been desirable to minimize corrosion and pitting of the various surfaces.

Test readings using Sample 789 were taken after the above work was complete and an average test value of 64.9 lb. was obtained. High spring pressures were also observed. The above indicated that surfacing of the plate had little or no effect on the test values in this case.

While high spring pressures were normally thought to lower the readings slightly--see Testing, Compression Report 48, September 3, 1954--it was decided to lower the spring pressure by inserting shims between the spring holder and the hot plate. The spring pressure was lowered to near 22 lb. by this procedure and additional tests were made with Sample 789. On successive days, averages of 60.0 and 60.2 lb. were obtained. These values were in good agreement with the desired average value of 60.1 lb.

It may also be remarked that a recheck on the above carried out about a month later yielded a somewhat higher average of 61.5 lb-- still well within the upper control limit (62.1 lb.) for this sample. When these results were obtained, it was believed that the instrument had been restored to a satisfactory operating condition and preparations were made for beginning the initial phases of the instrumentation study.

While an apparently satisfactory operating condition was obtained, the cause is not entirely clear as lowering the spring pressure usually increases Concora test results. This result was obtained in the previous study of the Concora instrument and has been reconfirmed in the present study.

PART 3. EXAMINATION OF THE INSTITUTE'S FLUTER

A. General

As mentioned previously, it was found necessary to return the Institute's Concora fluter to the manufacturer for reconditioning and replating the rolls and slider. The machine was returned to The Institute of Paper Chemistry on November 13 and it was understood that the hot plate, rolls, heaters, bearings, etc., were all replaced--giving an essentially new machine. After less than an hour's operation, it was observed that the fluted specimens exhibited leaning flutes.

The cover was then removed and it was immediately noted that wear was taking place under both rolls at only two locations (for each roll) on the hot plate. When the rolls were removed, it was found that

1. The plating had flaked off in both wear spots under each roll. Flakes of the plating were attached to the under side of the roll near its outside periphery.

2. The plating had worn off smoothly near the grooves on the hot plate.

3. The slider was not moving smoothly.

Mr. Ascani of the Liberty Engineering Corporation then smoothed the roll and hot plate surfaces using No. 400 Carborundum paper. Partial assembly indicated some improvement but not sufficient to produce a smooth sliding action. All plating was then removed from the sliding surface of the slide and associated surfaces using a file and coarse carborundum paper. After considerable work along this line, partial reassembly indicated that a much smoother slide action was being obtained. (Note: Mr. Ascani expressed the opinion that the plating used was either a copper-nickel-chrome or cadmium plating, rather than the hard chrome usually applied to the machine.)

At this point the machine was reassembled; however, no improvement in flute shape had been obtained as leaning flutes continued to be produced. Roll pressures were high--near 30 lb. with rolls stopped, and from 25 to 29 lb. with the rolls in operation. Relieving spring pressure appeared to have little effect on the actual force required to separate the rolls. When the rolls were separated during the pressure measurements, it was observed that the pressure roll did not move back in a straight line. It appeared to rotate clockwise slightly at small separations followed by a counterclockwise rotation at larger separations. The pivot point appeared to be the high spot on the hot plate on the left side.

Because the machine was unusable, it was agreed that

1. Mr. Ascani would return it to their shops to

   a. Resurface hot plate and replate rolls and hot plate

   b. Replate slider and associated surfaces

2. The rolls, hot plate and slider from machine No. 316 were also taken by Mr. Ascani for surfacing and plating.

On December 5 both Concora tester No. 210 and the hot plate and rolls for the second machine (No. 316) were returned to the Institute. At that time the manufacturer indicated that both hot plates had been resurfaced and hot plates, rolls, and slides replated with a hard chromium plating. It was also noted that fluter No. 210 had been in operation in the manufacturer's plant for several days and appeared to be in normal operating condition.

Concora fluter No. 210 was immediately put into operation and fluter No. 316 was reassembled with the assistance of Mr. Ascani of the Liberty Engineering Corporation. When the first specimens were fluted in No. 210, it was observed that leaning flutes were being produced. After removal of the cover, it was observed that

1. Roll pressure was high--a force in excess of 30 lb. (limit on spring scale used) was required to move the pressure roll.

2. Wear on the hot plate was occurring unevenly.

Similar conditions were noted in No. 316 when it was brought up to temperature. The plating, however, appeared to be satisfactory on both machines.

B. Control Chart Analysis of Test Results from Concora Fluter No. 210

Since December 5 daily or twice daily checks on the performance of fluter No. 210 have been made using the standard sample of medium employed in the Institute's calibration program. The results obtained during December are summarized in Table I and graphically illustrated in Figure 2. With regard to Figure 2 it may be noted that the abscissa represents date of test as specified in Table I. Because in some instances more than one check was made on a given day or in other instances a weekend intervened between tests, equal time intervals did not exist between checks as is implied by the chart. It was felt, however, that this form of the chart best illustrated the essential trends in the data.

Referring to the table or to Figure 2, it may be noted that flute height measurements were first made on December 10. With the above in mind, it may be noted that

1. From December 10 to 12, flute heights near 185 points were recorded while test readings ranged from 63.5 to 65.6 lb.

2. On December 15, 16, and 17, flute heights were near 195 points and test readings ranged from 63.6 to 59.6 lb. Coincident with the above changes, the incidence of leaning flutes appeared to decrease.

3. On December 18, 19, and 22, a trend to lower flute heights may be observed while test readings increased.

4. On December 23 the flute height increased again to near 195 points and the test reading decreased.

TABLE I

CONCORA RESULTS (SERIAL NO. 210)

Date	Time	Concora Flat Crush, lb. (n=20) Average	Range	Flute Height,[a] points First Flute Average	First Flute Range	Fifth Flute Average	Fifth Flute Range	Tenth Flute Average	Tenth Flute Range	Maximum Av. Difference in Flute Height, points
12- 5-58	7:45 p.m.	61.25	21.5	—	—	—	—	—	—	—
12- 5-58	10:20 p.m.	63.00	21.5	—	—	—	—	—	—	—
12- 8-58	9:45 a.m.	63.55	16.0	—	—	—	—	—	—	—
12- 8-58	4:00 p.m.	58.38	20.5	—	—	—	—	—	—	—
12- 9-58	8:00 a.m.	66.45	17.0	—	—	—	—	—	—	—
12- 9-58	4:00 p.m.	62.60	10.0	—	—	—	—	—	—	—
12-10-58	8:20 a.m.	63.70	22.5	203.5	13.5	187.5	20.0	208.2	15.0	20.7
12-10-58	4:15 p.m.	63.05	15.0	202.1	8.0	185.0	6.5	207.2	11.0	22.2
12-11-58	8:30 a.m.	65.62	20.5	205.4	13.5	184.2	7.5	200.0	24.0	21.2
12-12-58	8:30 a.m.	65.28	12.5	200.7	11.0	185.3	15.0	212.2	11.5	26.9
12-15-58	8:30 a.m.	63.55	15.5	207.3	8.0	193.8	6.0	208.1	13.0	14.3
12-16-58	8:30 a.m.	62.35	11.0	202.5	5.5	195.1	2.5	208.9	15.0	13.8
12-17-58	8:30 a.m.	59.58	19.5	203.7	5.5	195.1	8.5	208.1	18.0	13.0
12-18-58	8:30 a.m.	61.25	17.0	210.6	47.0	192.9	7.0	205.5	11.0	17.7
12-19-58	8:30 a.m.	63.20	17.5	201.9	8.0	190.5	13.0	204.7	13.0	14.2
12-22-58	8:30 a.m.	63.82	10.5	200.3	10.5	189.6	14.5	205.4	18.5	15.8
12-23-58	8:30 a.m.	59.95	16.0	201.3	9.0	194.3	9.0	206.6	7.0	12.3
12-29-58	8:30 a.m.	63.28	18.0	202.2	4.5	187.8	11.0	207.7	9.5	19.9
12-30-58	8:30 a.m.	60.88	19.5	203.7	4.0	195.3	14.0	210.9	9.0	15.6
Average		62.67[b]	16.9[b]	203.5	11.4	190.5	10.3	207.2	13.5	17.5
Average		62.73[c]	16.5[c]							

[a] Average of readings on Specimens 1, 5, 10, 15 and 20.

[b] Average based on all data.

[c] Average based on period 12-10 through 12-30-58.

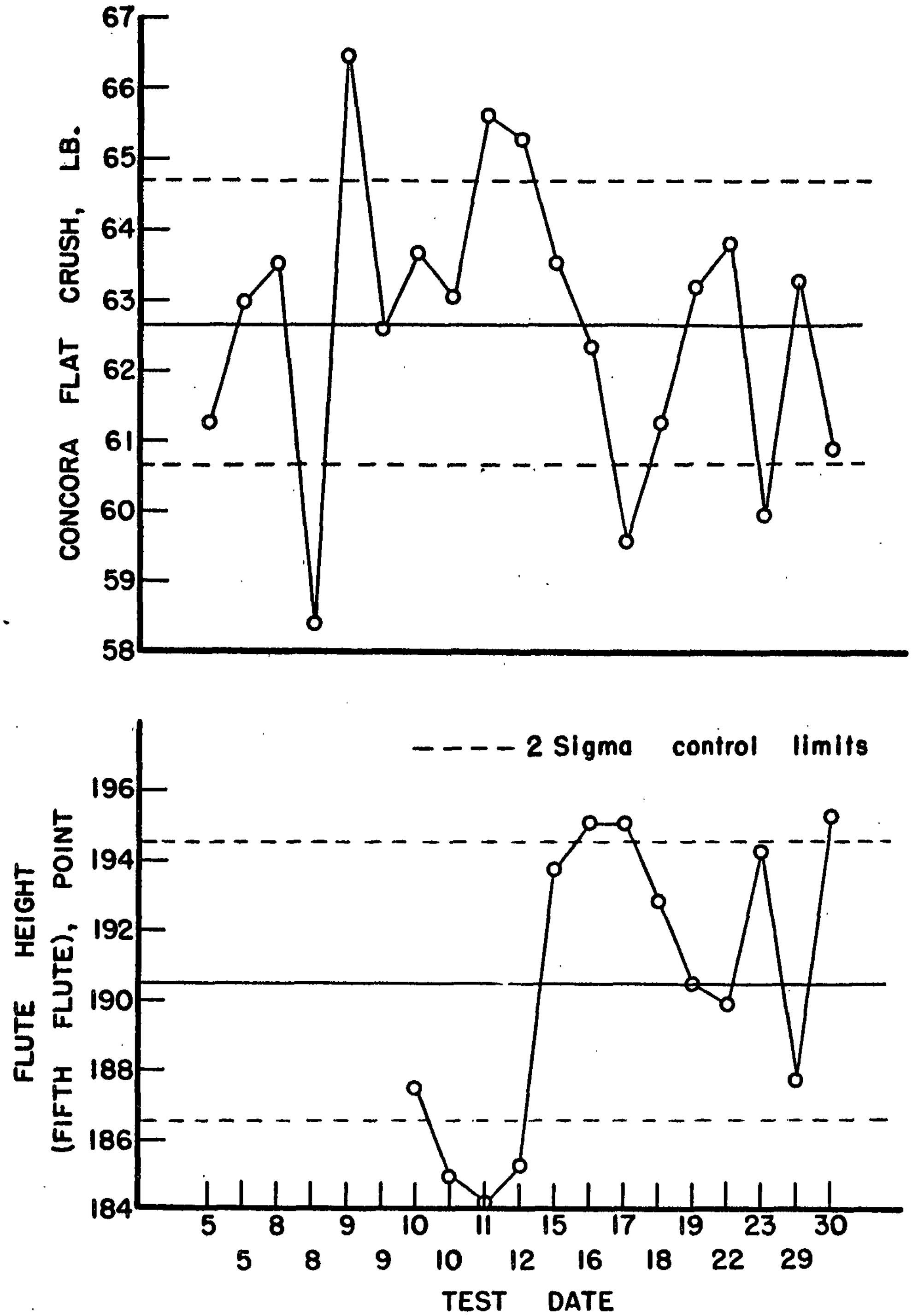


Figure 2

Control Charts of Concora Test Readings and Flute Height During December

After Reconditioning of the Fluter

5. On December 29 the flute height decreased to near 188 points and the test reading increased. On December 30 the converse occurred.

Two sigma control limits are also shown in Figure 2 for both the flute height and Concora test reading. Their limits indicate that significant changes in both Concora test readings and flute height occurred during the past month. There is further a significant coincidence between out-of-control points on the flute height and test reading charts.

In Table II may be found a control chart record for the Institute fluter in January. The results are graphically illustrated in Figure 3, together with the previously reported results for December. It may be noted in the table or figure that the test results appeared to be somewhat more uniform during the first half of the month and were not so clearly dependent on flute height as in the previous month. Toward the latter part of the month the results appeared to vary over a somewhat greater range. On an over-all basis, the monthly average of 61.96 lb. was about 1% lower than that recorded for December and about 3% greater than the former operating level of the machine.

During the first weeks of February the daily checks on the condition of the machine were discontinued. They were re-instituted on February 13 with one change in procedure. In the prior testing, flute height measurements were made on flutes 1, 5 and 10 of specimens 1, 5, 10, 15 and 20. Because of the observed differences in flute height from specimen to specimen, it was thought desirable to increase the number of flute height measurements. For

TABLE II

CONCORA RESULTS DURING JANUARY, 1959

Date	Concora Flat Crush, lb. (N 20)		Flute Height, points (N=5)					
			First Flute		Fifth Flute		Tenth Flute	
	Average	Range	Average	Range	Average	Range	Average	Range
1- 2-59	62.62	18.0	205.1	7.0	190.7	13.0	210.3	14.5
1- 5-59	61.30	21.0	200.4	9.5	187.5	21.0	202.9	32.0
1- 6-59	60.42	15.0	207.1	5.5	192.7	5.5	207.9	6.5
1- 7-59	60.38	18.5	205.2	7.0	194.4	4.0	210.3	6.0
1- 8-59	61.10	14.0	199.9	12.5	192.7	4.0	209.2	8.0
1- 9-59	61.98	19.0	210.2	10.5	198.6	5.0	211.4	15.5
1-12-59	61.75	17.5	205.1	6.0	196.3	7.0	210.1	10.0
1-13-59	63.20	18.0	204.7	11.0	193.4	6.0	211.1	8.0
1-15-59	60.90	19.5	204.9	8.5	189.8	7.5	207.8	7.5
1-16-59	61.98	26.5	204.0	10.5	188.4	16.5	208.4	6.0
1-19-59	61.40	21.5	205.3	9.0	191.0	10.5	211.7	7.0
1-20-59	63.35	22.5	205.6	4.5	195.3	9.0	204.5	7.0
1-21-59	59.18	18.0	206.6	4.5	193.5	2.5	208.7	8.0
1-22-59	62.28	26.0	203.3	6.5	192.2	5.5	202.5	10.0
1-23-59	63.40	19.0	203.3	11.5	189.4	13.5	203.1	19.0
1-26-59	63.88	23.5	202.6	3.0	190.6	12.0	202.5	10.0
1-29-59	64.28	23.0	196.5	21.5	186.1	26.0	204.4	15.0
Av. (Jan.)	61.96	20.0	204.1	8.7	191.9	9.9	207.5	11.2
Av. (Dec.)	62.67	16.9	203.5	11.4	190.5	10.3	207.2	13.5

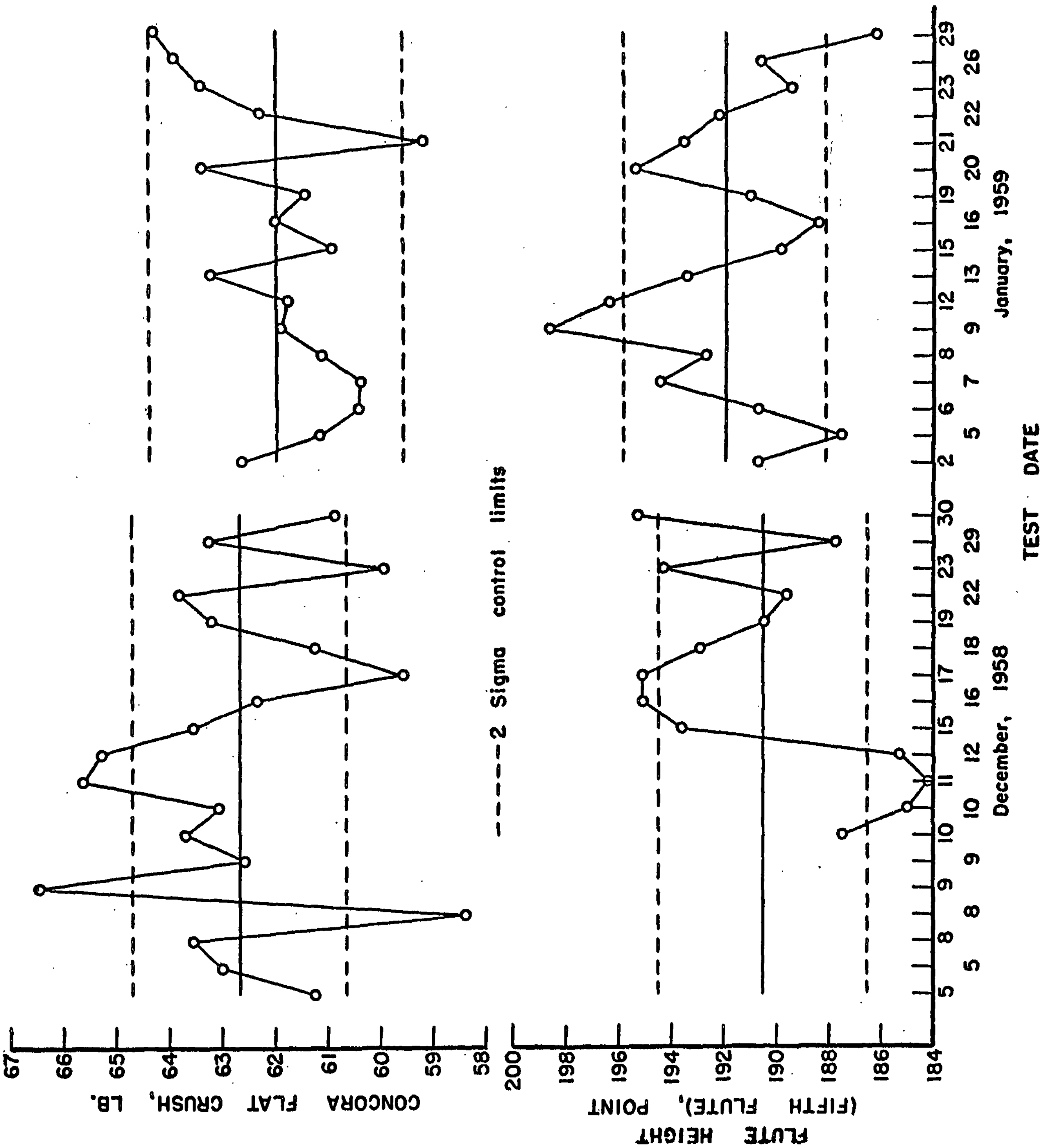


Figure 3. Concora Medium Test Control Chart During January, 1959

this purpose, flute height measurements were made on Flute 5 of each of the 20 specimens tested on each day. At the same time the height measurements on the end flutes were temporarily discontinued.

The results obtained through March 9 are summarized in Table III and graphically illustrated in Figure 4. As may be noted in the table or figure, the tendency for test results to vary with flute height appeared to be more clearly defined than during the previous month--perhaps because the increase in the number of flute height measurements (5 to 20) resulted in more precise flute height averages. In any event, the increase in number of flute height measurements gave closer control limits and it may be concluded that significant changes in flute height were observed on February 13, 24, 25, 26, 27, and March 5. In general, lower values of flute height were associated with higher averages and vice versa.

TABLE III

CONCORA RESULTS DURING FEBRUARY AND EARLY MARCH

Date		Concora Flat Crush, lb. Average (n=20)	Concora Flat Crush, lb. Range	Flute Height, points Average (n=20)	Flute Height, points Range
2-13-59		62.82	26.5	188.3	28.0
2-19-59		60.05	19.0	195.2	9.0
2-20-59		60.25	13.5	194.0	11.5
2-23-59		60.55	16.0	195.7	9.5
2-24-59		64.00	21.5	191.9	15.0
2-25-59		58.80	13.0	196.8	9.0
2-26-59		61.98	14.5	191.4	16.5
2-27-59		59.20	16.0	197.8	14.5
3- 5-59		59.58	17.0	196.9	11.0
3- 9-59		60.58	20.5	195.0	12.0
	Average	60.78	17.8	194.3	13.6

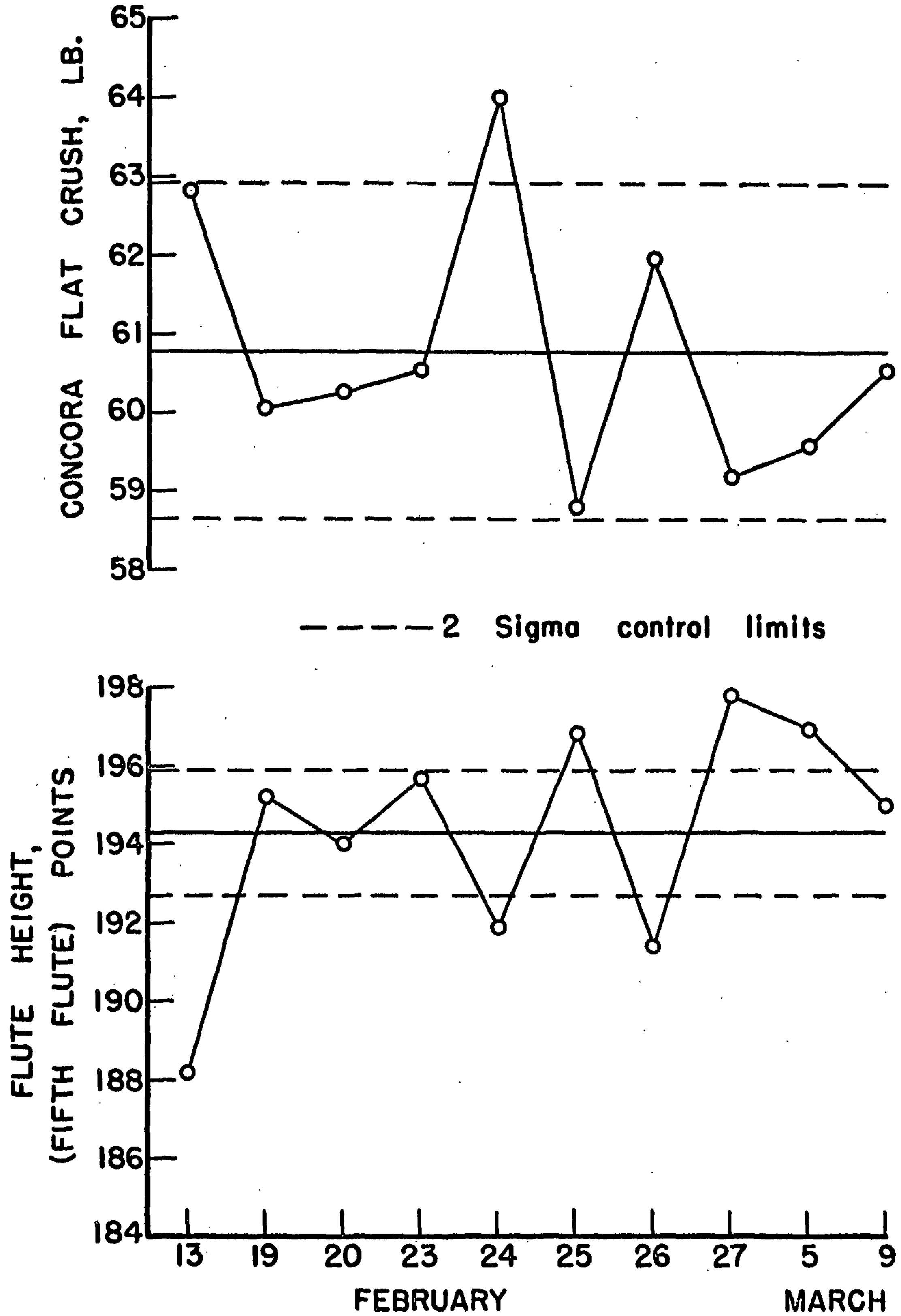


Figure 4. Concora Medium Test Control Chart During February-March, 1959

The over-all averages for the monthly periods are summarized below:

	Concora Flat Crush, lb.	Diff., % [a]	Diff., % [b]	Flute Height, points	Diff., % [b]
Former test level	60.12	--	-4.1	--	--
December test level	62.67(19)[c]	+4.2	--	190.5(13)[c]	--
January test level	61.96(17)[c]	+3.1	-1.1	191.9(17)[c]	+0.7
February-March test level	60.78(10)[c]	+1.1	-3.0	194.3(10)[c]	+2.0

[a] Based on former test level.

[b] Based on December test level.

[c] The number in parentheses indicates the number of sample averages included in the over-all average.

As may be seen in the table, current test results appear to average about 3% lower than those obtained during December after the machine was reconditioned and are near the former operating level for the machine. This decrease in test results appears to be associated with about a 2% increase in flute height.

While the test readings and flute height trends are not perfectly correlated (and the control chart limits make this understandable), it is believed that the above demonstrates that test readings and flute height may be related at least under some conditions. More importantly, the above indicates that a given instrument may not flute specimens in an identical manner over extended periods of time and that differences in test instruments may arise from this cause.

To illustrate these results in another way, a plot of Concora flat crush vs. flute height may be found in Figure 5. While considerable scatter occurs in the graph, a correlation of the results yielded an apparently significant correlation coefficient of -0.69. The least squares equation for the regressive line was as follows:

$$y = 124.00 - 0.323\ x$$

where y = Concora flat crush, lb.

x = flute height, points

This would seem to indicate that a change of one point in caliper corresponds to about 0.3 lb. in Concora test or about 0.5%. On this basis, if it were desired to hold variations in Concora flat crush from this cause to within ± 1%, average flute height should be held within ± 2 points.

As mentioned previously, the flute height measurements discussed above represent the average height based on measurement of the fifth flute from each of 5 specimens (December and January) or 20 specimens (February-March). The range, that is, the difference between maximum and minimum values, is oftentimes quite appreciable. For example, during December

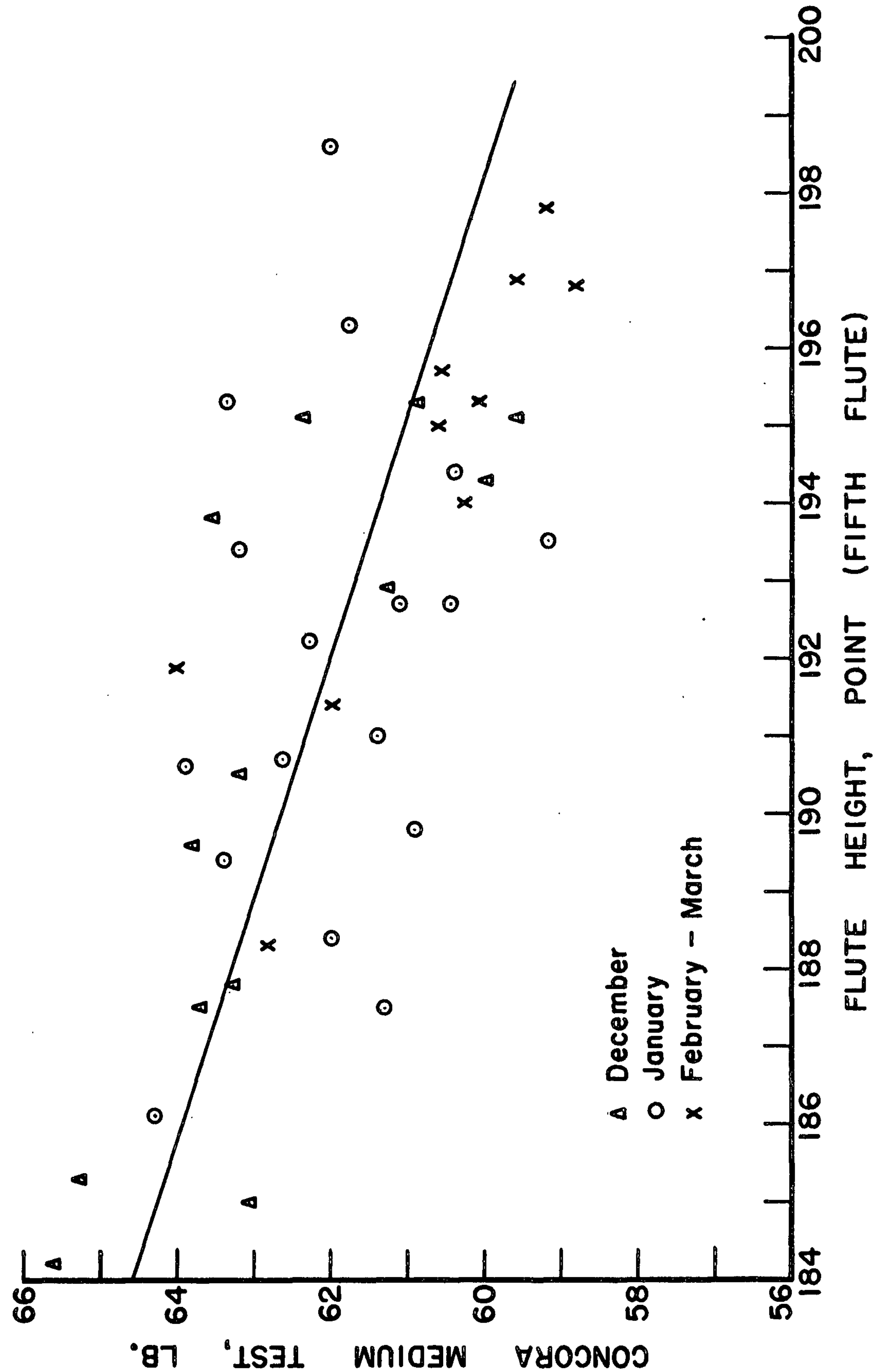


Figure 5. Relationship Between Flute Height and Concora Flat Crush

it varied from 2.5 points on 12-16 to 20.0 points on 12-10-58. In January, it ranged from 2.5 points on 1-21 to 26.0 points on 1-29-59. This would seem to indicate that even from specimen to specimen considerable differences in flute height may occur.

The range may also be used to estimate the standard deviation of the flute height. Using the average values for the range (based on fifth flute values) the following values of standard deviation may be obtained.

	Average Height, points	Average Range, points	Standard Deviation, points
Dec. (n=5)	190.5	10.3	4.4
Jan. (n=5)	191.9	9.9	4.3
Feb.-March (n=20)	194.3	13.6	3.6

As may be seen from the above, the estimated standard deviations are in the neighborhood of 3.5 to 4.5 points. This would indicate that, if the height of the middle flute were measured in a large number of specimens, about 68% of the measurements would be found to be within limits of ± 3.5 to 4.5 points of the average and about 95% of the measurements would be within ± 7 to 9 points of the average. (Note: This holds true only if statistical control is maintained during the test period; deviations from statistical control would increase the number of extreme values recorded). These differences in flute height appear to be greater than would be expected from flute-to-flute of well made single-faced board.

This variance in flute height from specimen to specimen may have some bearing on the relatively large standard deviation associated with

Concora tests. The following is taken directly from Reference 2 in which Maltenfort & Long discuss this particular subject:

> "... It is interesting to compare the CMT test to other paper tests like burst on liners and flat crush on combined board, which are tests accepted as standard by ASTM and TAPPI.
>
> On a comparable sampling basis, details of which must be omitted here for the sake of brevity, the table below shows that CMT of medium compares favorably with these standard tests. Shown are the test levels and the average plus or minus range with which the average of any participant in the round robin must agree with the pooled average of all.

Burst Liner, lb. n = 20		Flat Crush, Combined Board, lb. n = 10		CMT, Medium, lb. n = 10	
A	B	A	B	A	B
100	± 4	330	± 7	75	± 4.5

> A = average test level, lb.
> B = ± average range, lb.
> n = sample size/average. "

In terms of the absolute units reported by Maltenfort and Long, one may be left with the impression that the flat-crush test is appreciably more variable than the burst test with the CMT approaching the burst test. It may be suggested, however, that a more appropriate method of comparison would be to convert the cited plus or minus ranges to percentages of the average. For example, consider two tests with averages of 100 and 1000 units. If each had a standard deviation of 50 units, for many purposes it would be concluded that the test with an average of 100 units and a standard deviation of 50 units was the more variable. With this in mind, the values noted above have been converted to percentages. In addition, a correction for sample size has been made by multiplying the flat crush and CMT values by the factor $\sqrt{10/20}$ since the standard error is inversely dependent on the square root of the number of readings. The table now assumes the form shown below:

		Average	Range	Per cent Range
Burst	(n = 20)	100	± 4	± 4.0
Flat crush	(n = 10)	330	± 7	± 2.1
	(n = 20)	330	--	± 1.5
CMT	(n = 10)	75	± 4.5	± 6.0
	(n = 20)	75	--	± 4.2

On this basis, the following conclusions might be reached:

1. Closest agreement between participants in the round-robin must be expected in the flat-crush test.

2. Considerably wider limits on a percentage basis must be allowed in the case of either the burst or CMT tests.

Somewhat similar results have been previously reported to the members of the FKBI (5). For example, the following results were obtained when the flat-crush and Concora tests were compared:

		Combined Board Flat Crush	Concora Flat Crush
Average, p.s.i.		33.48	33.10
Standard deviation, p.s.i.		1.23	2.03
Standard deviation, %		3.7	6.1
Two standard error, p.s.i.		± 1.10	1.82
Two standard error, %	n = 5	± 3.3	± 5.5
	n = 10	± 2.3	± 3.9
	n = 15	± 1.9	± 3.2

As may be noted from the table, greater standard deviations and errors are encountered with the Concora test--in qualitative agreement at least with the previously noted results.

If it can be accepted on the basis of the above that

1. Concora test results are appreciably more variable than flat-crush results--both expressed on a percentage basis

and 2. Variations in flute height from specimen-to-specimen may occur which seem surprisingly great;

then, it may seem reasonable to suggest that the two may be interrelated. In other words, it appears likely that large variations in flute height from specimen-to-specimen may be one cause of variations in the test load. It may be remarked in this connection that examination of the Feb.-March test results indicated that extremely high individual load values frequently coincided with specimens of low flute height.

The above discussion of flute height has been focussed on the averages associated with measurements of height on one of the middle flutes, namely, the fifth flute. During December and January, measurements were also made on the first and tenth flutes, that is, the two end flutes. The over-all average flute heights for these two months are repeated below:

	December		January	
Flute No.	Flute Height, points	Difference points	Flute Height, points	Difference, points
1	203.5	+ 13.0	204.1	+ 12.2
5	190.5	--	191.9	--
10	207.2	+ 16.7	207.5	+ 15.6

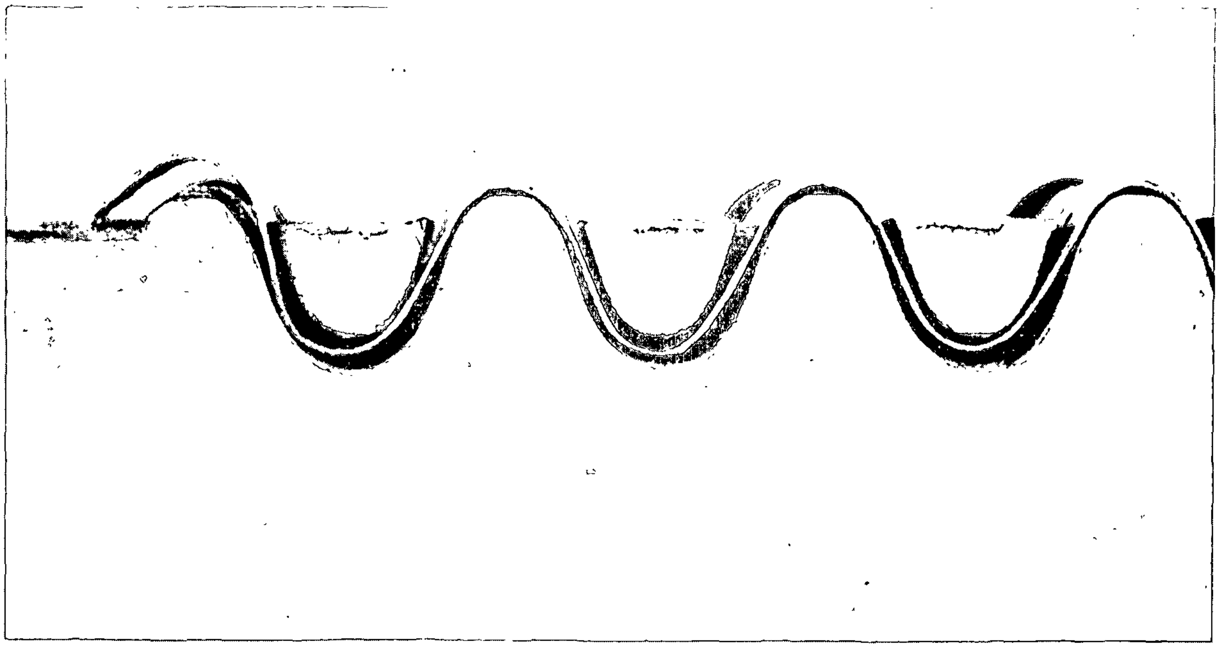
It may be noted that the end flutes average height was considerably greater than for the middle flute. These differences cannot be attributed to changes in height due to conditioning because, as will be developed in later pages, such differences may be found immediately after specimens are removed from the rack. Their presence is attributed tc the taping operation. For example, in Figure 6 a typical specimen is shown in place in the rack and comb as it appears just before the taping operation. In the photograph, it may be noted that the flutes do not bottom in the rack--typical of all specimens. As a result, when tape is applied and pressure is applied by thumb or roller, the end flute is pressed down so as to fully form to the rack height. The other flutes are not similarly affected and consequently the end flutes exhibit high flute heights as compared to the middle flutes.

While it would be desired to obtain specimens with uniform flute height from flute-to-flute, the defect is thought to be less serious than the changes in flute height from specimen-to-specimen from day-to-day previously discussed. Additional discussion of means of eliminating the high end flutes may be found in later pages of this report.

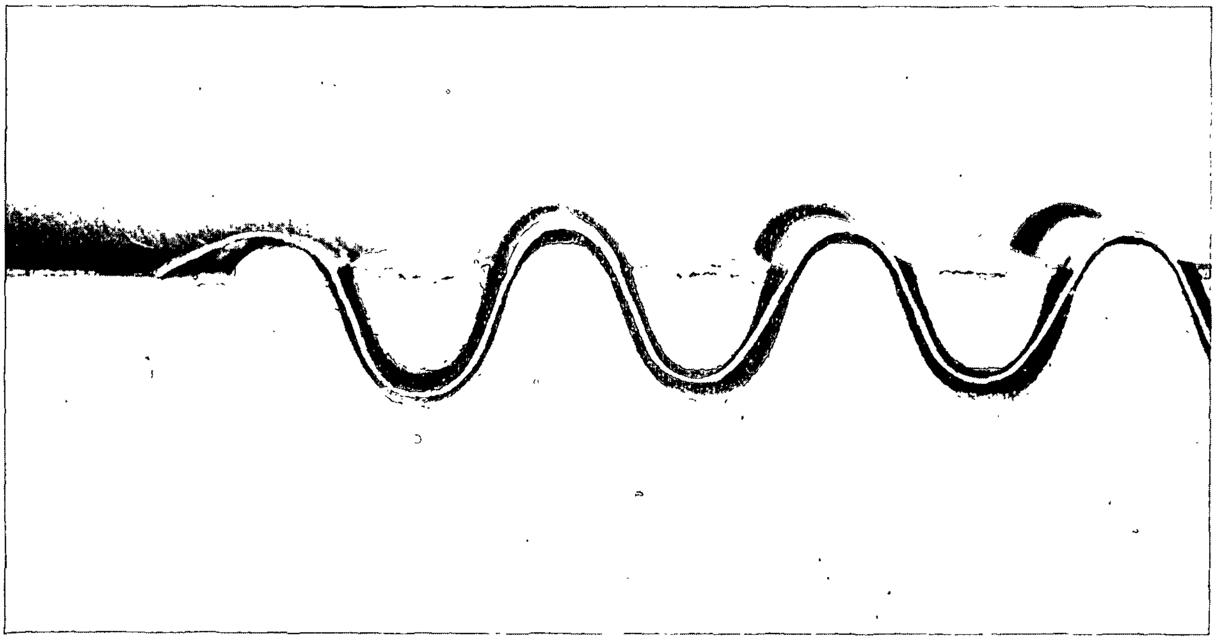
Summarizing the discussion, thus far analyses of the performance of the Institute's reconditioned fluter appears to result in the following conclusions:

1. Significant changes in test level occurred during the test period.

2. Changes in test level appeared to be partially related to changes in flute height. On the average, it appeared that an increase in



Typical Specimen in Rack and Comb



Same Specimen with End Flute Held Down as in Taping Operation

Figure 6. Rack and Comb Action

flute height of one point resulted in a decrease in test load of about 0.3-pound--or about 0.5%. This suggests that if flute height can be stabilized, more stable test levels may be obtained.

3. The variance in flute height from specimen-to-specimen was remarkably large. For example, the average ranges for December and January ($n = 5$) were near 10 points. The evidence of 1 and 2 above coupled with the frequent coincidence of high Concora test readings with low flute height specimens suggests that a portion of the test standard deviation may arise from differences in flute height from specimen-to-specimen. Conversely, if flute height uniformity can be improved, improvement in test standard deviation may result.

4.. Within a given specimen, the end flutes exhibit considerably greater heights than do the middle flutes.

It is believed that the above, coupled with evidence from previous studies and from other work reported in later pages of this report, indicates that variations in flute height within and between specimens may be one cause for differences in Concora test readings within or between machines. Among the variables which may affect the molding of the flutes and, consequently, the flute height, are temperature, pressure, moisture content and the physical characteristics of the medium itself. Roll temperature and moisture content prior to forming have seemed to have little effect on test readings when varied over considerable ranges. The control chart analyses cited herein indicate that, even with a given medium, substantial changes in flute height and test readings can occur. These remarks suggest that the effective pressure between rolls may play a large part in causing differences in flute height and test readings. In the Concora fluter, the total force between rolls may be thought of as a resultant of two forces, namely, (1) the force exerted by the spring and (2) the frictional forces associated with movement of the rolls and slider. Wear, corrosion or build-up of caked deposits on the sliding surfaces has been observed to take place and it appears reasonable to conclude that such factors could alter the frictional forces sufficiently to cause differences in flute shape and test readings.

PART 4. OBSERVATIONS ON SLIDER WEAR

At various times, concern has been expressed that the forward top surface of the slider may rub against the rough under surface of the hot plate. In order to confirm the above, Concora fluter No. 316 was disassembled, dye was applied to the slider and other surfaces, and the machine was carefully reassembled. After assembly, 90 specimens were fluted and the machine was disassembled in order to examine the slider.

Wear marks were found in the following locations as illustrated in Figure 7A.

1. Forward top surface of slider

2. Under surface of back (nearest spring) right and left projections on slider and associated locations on the chrome plated ways.

3. Vertical sides of slider and recess.

A similar photograph of the slider on the Institute's fluter No. 210 is also shown in Figure 7B where the strong wear mark on the top right hand side of the slider is clearly visible.

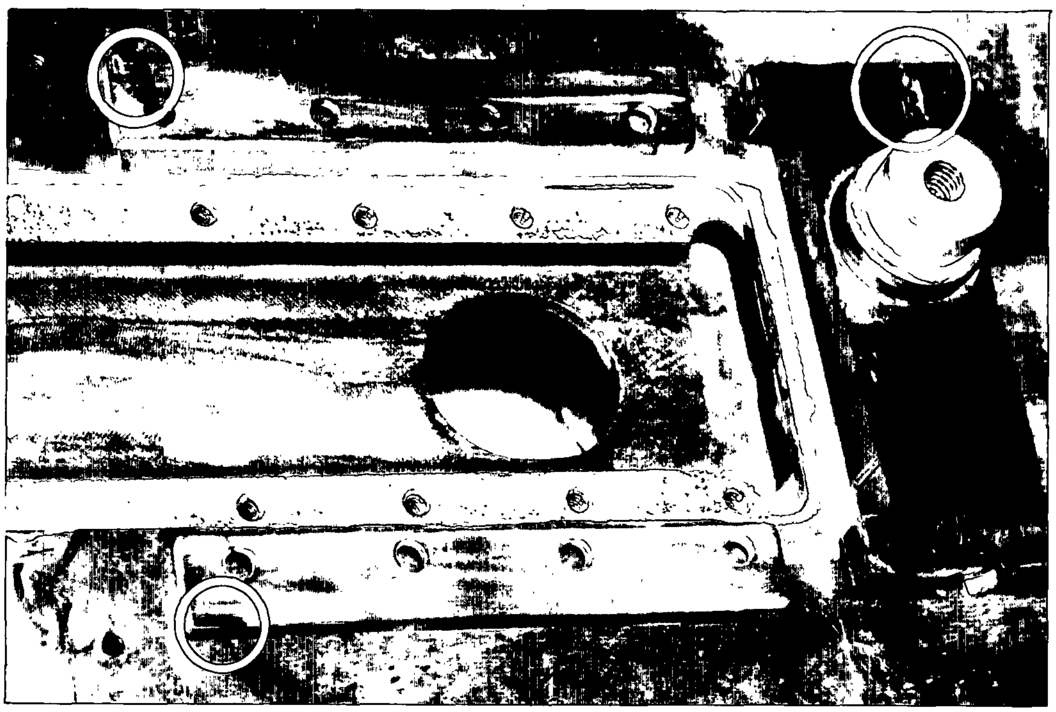


Figure 7A. Appearance of Slide on Fluter No. 316 After Fluting 90 Specimens

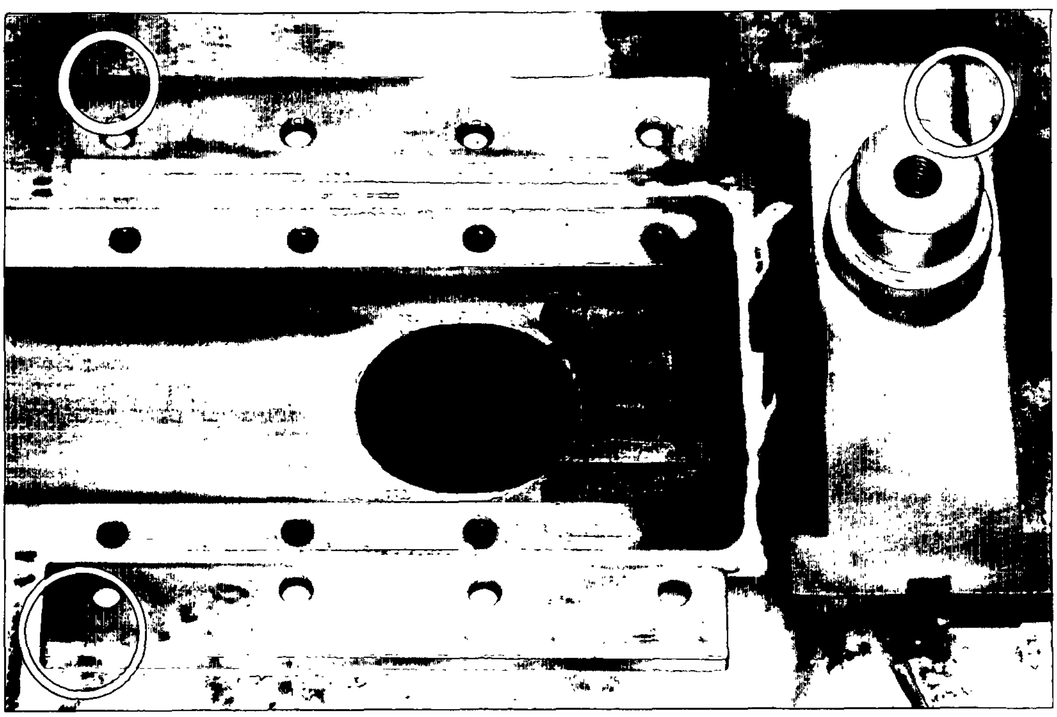


Figure 7B. Appearance of Slide on Fluter No. 210 After Several Weeks of Use

It should not be inferred from the above that wear marks may not be found in other locations, particularly if the instrument has been in steady use for a considerable length of time. The converse has usually been true; however, major evidence of wear has frequently occurred in the general locations noted above. As a matter of interest, it may be remarked that most recently the slider appears to be rubbing on the heating element itself. It should also be noted that the general term "wear" has been purposely used in the above remark. However, the marks observed more frequently resemble scratches rather than what might be termed a uniform wear pattern.

Items (1) and (2) above would indicate that the slider tends to rotate in a vertical plane. This seems to be in accord with a force diagram for the system, that is, the force of the spring and the reactive force between rolls form a couple tending to rotate the slider system about its center of gravity. To resist the rotational couple, pressure must be exerted in the general locations noted above. It also may be noted that the frictional forces act to oppose movement. Thus, when the rolls are moved apart, frictional forces add to the pressure exerted by the spring; the converse occurs when the rolls are attempting to move or are being moved together.

The preceding remarks appear to strengthen the viewpoint that the performance of the Concora fluter must be significantly dependent upon sliding friction between roll and hot plate and in the slider mechanism. Because "friction" is a notoriously difficult factor to control, it suggests that succeeding work should be concerned with means of reducing or removing the dependence of the instrumental performance on sliding friction.

PART 5. DEPTH MEASUREMENTS IN ROLLS AND RACK

Measurements were then made of the depth of the flutes of the rack using a depth micrometer. Similar measurements were also made on the pressure and drive rolls by laying the depth micrometer across two adjacent flute tips and determining the depth of the flute. Since the teeth on a roll lie on a circle, the rack and roll measurements are not strictly comparable; however, to a first approximation, they may be helpful in comparing observed and theoretical flute heights. The results are shown below:

	Average Flute Height, points	Maximum Height, points	Minimum Height, points
Pressure roll	189.4	190.4	188.4
Drive roll	188.3	189.0	187.2
Rack	188.7	189.4	187.8

As may be noted, the average flute heights of both roll and rack were nearly equal and relatively uniform. Some small differences in flute height might result, however, from the small differences in flute depth.

If, on the basis of the above measurements, it is assumed that the theoretical flute height for formed specimens should be in the neighborhood of 189 points, a comparison may be made with the actual measured values of flute height. For this purpose, one thickness of medium and the caliper of the tape used to hold the specimen should be added to the base figure of 189 points. This assumes that the Concora pressures are insufficient to cause any significant decrease in medium caliper at the flute tips and that pressures in the taping operation do not change the tape caliper. With this in mind, if 9 and 13 points are taken for the caliper of the medium and tape, respectively, a total theoretical flute height of about 211 points should be attained with formed specimens.

Referring back to Table I, it may be noted that center flute heights generally fall in the range from 185 to 195 points. The end flutes, on the other hand, generally range from 200 to 210 points. Thus, only the end flutes approach the theoretical flute height. Physically, this means that, as a general rule, the flutes formed by the Concora do not bottom in the rack---a fact which is generally quite visible to the eye (see also Figure 6). The closer approach of the end flutes to the theoretical flute height appears to occur in the taping operation because the "thumb" or roller used in applying the tape forces additional material into the last flute on each end of the specimen.

To illustrate the above results in another manner, specimens were cold-formed to the height of the rack using B-flute pins and suspended weights on each pin in one trial of 2 lb. and in a second trial of 3-1/4 lb. This was accomplished by laying a flat specimen over the rack and, starting on one end, progressively placing each pin to form successive flutes. After taping the specimens so formed, average flute heights of 208.6 and 208.1 points were obtained. They were therefore in relatively close agreement with the theoretical flute height cited above.

PART 6. FLUTE SYMMETRY

Occasional references have been made in the past with regard to leaning flutes. To place such statements on a more objective basis, a technique for measuring the sidewall angle of the fluted specimens is being developed. In brief, it consists of placing a fluted specimen (taped to a flat steel bar) in contact with a sheet of film and exposing the film to form an image of the fluted contour. A suitably prepared specimen is shown in Figure 8. Frontal illumination has been used in order to obtain a sharp image of the front surface of the specimen; shadows then form on inside surfaces of the flute. This is of no consequence, however, as all measurements may be based on the outside contour. The resulting negative may then be enlarged to a suitable degree (about a 14 times enlargement was employed herein) onto sheet film and the angles formed by the sidewalls of the flute may then be measured. An example of the type of enlarged image is shown in Figure 9. The results of a preliminary trial of the procedure may be seen in Table IV. As may be noted in the table, the average differences in side wall angle varied from 2.3 to 5.4 degrees for the middle flutes. Such differences appear greater than would be expected in well-formed flutes and actually are visible to the eye in examination of the fluted specimens themselves.

TABLE IV

FLUTE SYMMETRY OR DEGREE OF LEAN OF CONCORA SPECIMEN

Flute No.	Flute Side Wall Angle, °[a] Right Side	Left Side	Difference
1	65.1	65.9	+ 0.8
2	64.3	60.0	- 4.3
4	65.5	60.1	- 5.4
5	65.0	59.9	- 5.1
9	63.6	61.3	- 2.3
10	69.3	60.9	- 8.4

[a] Measured with respect to the horizontal baseline through the base of the flutes.

The method is not a rapid one; however, it does enable measurements of flute symmetry to be made where it is desired to include such measurements in a periodic check of a given machine. A record of past measurements of this type might be useful in diagnosing the cause of trouble when difficulties are encountered in the calibration of a given machine.

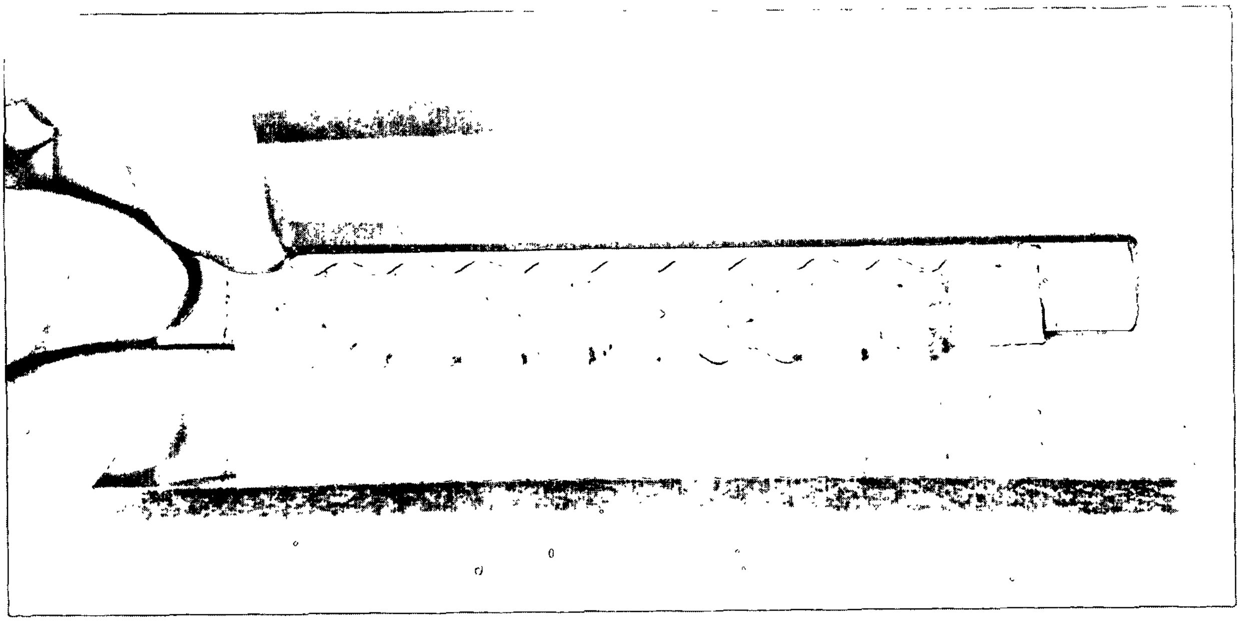


Figure 8. Prepared Specimen in Place on Sheet Film

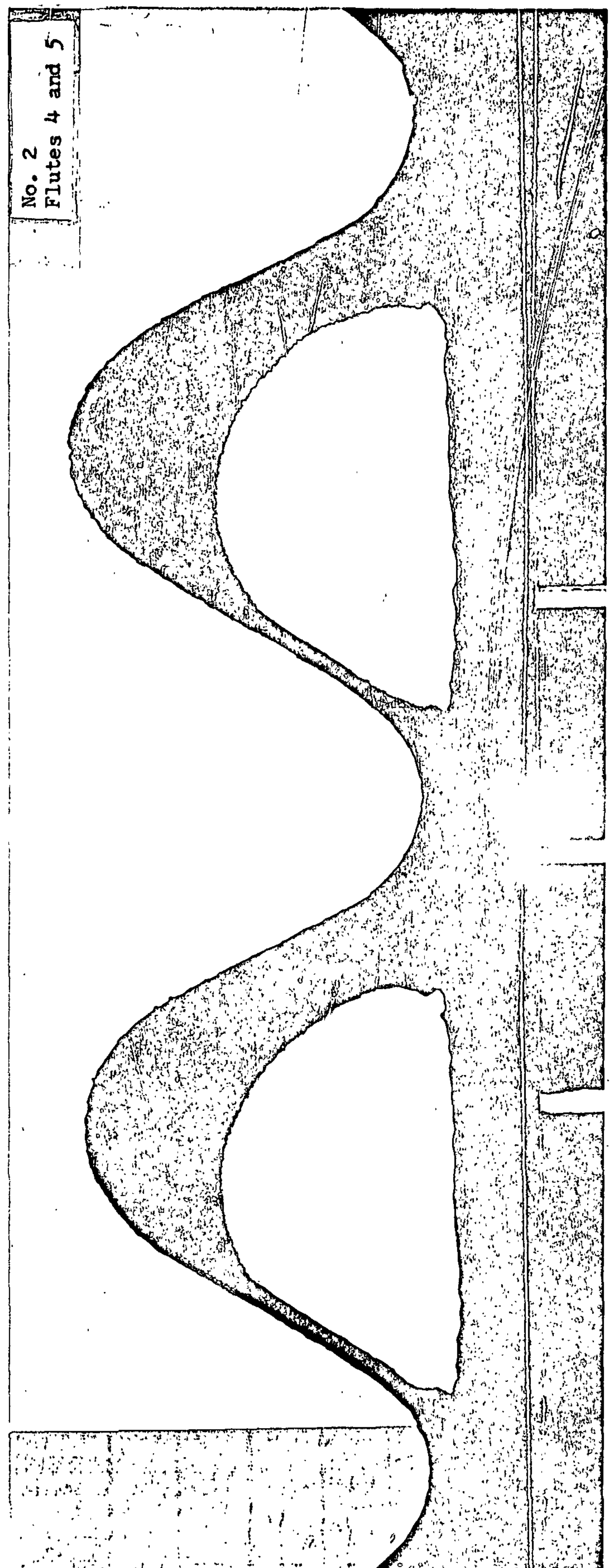


Figure 9. Enlarged Image of Flutes Formed by Concora

(Note: Heavy shadows obscure inside flute surface)

PART 7. EFFECT OF SPRING PRESSURE

As mentioned in the previous remarks, it was considered desirable to repeat the earlier work involving the effect of spring pressure. For this purpose, the spring pressure was varied by inserting shims between the spring and retainer or between the retainer and hot plate. Spring pressures of about 15, 22, and 30 pounds were studied. The Concora results are summarized in Table V. As may be noted in the table, a decrease in spring pressure from 22 to 15 lb. produced about 2.8% increase in Concora results on the average. In going to higher pressures, that is, from 22 to 30 lb., a decrease in flat crush of 3.1% was registered. While the differences in flat crush were small, they appear to be in qualitative agreement with previous results although the previous work indicated that lowering the pressure had a greater effect than increasing the pressure.

It was noted in the previous study that a change in flute caliper occurred as the pressure was changed. Measurements of flute caliper (including the thickness of tape) were also made on specimens fluted at each pressure in this study using a dial micrometer adjusted to exert a slight pressure on the flute. Height measurements were taken on the two end and one of the middle flutes from each of three specimens. The average values are summarized in Table VI. Referring to the table, it may be noted that a change in flute height does appear to be associated with pressure changes induced as described herein. Increasing the pressure appears to tend to increase the flute height. Because flat crush may be dependent in part on the fluted height of the specimens, it might be expected that increasing the flute height would lower the readings.

TABLE V

EFFECT OF SPRING PRESSURE ON CONCORA FLAT CRUSH

Concora Flat Crush, p.s.i.

Spring Pressure, lb.		Sample Number 1898	1897	1894	Composite Average	Diff., % [a]
22	Trial 1	32.8	41.9	34.6		
	Trial 2	32.1	39.9	34.4		
	Average	32.4	40.9	34.5	35.9	
15	Trial 1	34.6	42.8	35.1		
	Trial 2	33.3	41.0	34.9		
	Average	33.9	41.9	35.0	36.9	+2.8
30	Trial 1	32.8	40.8	33.2		
	Trial 2	31.7	38.5	32.3		
	Average	32.2	39.6	32.7	34.8	-3.1

[a] Based on 22-lb. results as reference.

TABLE VI

EFFECT OF SPRING PRESSURE ON FLUTE CALIPER

Spring Pressure, lb.		Flute Caliper, points 1898	1897	1894	Average	Diff., % [a]
			End Flute			
22	Trial 1	199.2	198.8	196.7		
	Trial 2	198.0	196.8	197.2		
	Average	198.6	197.8	197.0	197.8	--
15	Trial 1	193.8	197.0	198.0		
	Trial 2	192.7	199.8	195.7		
	Average	193.2	198.4	196.8	196.1	-0.9
30	Trial 1	206.5	207.0	204.5		
	Trial 2	206.0	209.7	206.3		
	Average	206.2	208.4	205.4	206.7	+4.5
			Center Flute			
22	Trial 1	186.5	186.2	193.7		
	Trial 2	191.3	195.7	194.0		
	Average	188.9	191.0	193.4	191.1	--
15	Trial 1	175.8	186.3	190.8		
	Trial 2	183.3	188.8	184.7		
	Average	179.6	187.6	187.8	185.0	-3.2
30	Trial 1	197.2	199.3	199.8		
	Trial 2	197.3	200.3	198.0		
	Average	197.2	199.8	199.4	198.8	+4.0
			End Flute			
22	Trial 1	204.7	211.0	208.3		
	Trial 2	205.3	207.3	208.5		
	Average	205.0	209.1	208.4	207.5	
15	Trial 1	204.5	207.0	202.2		
	Trial 2	205.3	207.0	205.2		
	Average	204.9	207.0	203.7	205.2	-1.1
30	Trial 1	206.7	204.2	207.8		
	Trial 2	206.0	206.7	208.5		
	Average	206.4	205.4	208.2	206.7	-0.4

[a] Based on 22-lb. results as reference.

It may be further noted that a considerable difference in flute height may exist between end and center flutes. (Note: Center flutes vary somewhat in height but usually the differences are much less than between center and end flutes.) For example, at 22-lb. pressure, the end flutes averaged 207.5 and 197.8 points, while the center flutes averaged 191.1 points, a maximum difference of 16.4 points. Similar differences exist at the other pressures. In part, this appears to occur in the taping operation as the pressure used in applying the tape tends to distort the end flutes. The rack supplied with the instrument used above had apparently been modified by cutting away the outer portions of the rack in an effort to correct this situation; however, differences in flute height appear to persist.

PART 8. EFFECT OF BLOCKED PRESSURE ROLL

As mentioned previously, free movement of the pressure roll may not occur for a number of reasons. These might include such items as insufficient or inadequate lubrication of sliding surfaces, corrosion or pitting of sliding surfaces, roll wear, warping of the hot plate, etc. In general, it would be expected that such a condition would become evident when measurements of the spring pressure were made; however, it was thought desirable to simulate the effect in this phase of the study. In connection with this topic, it may be mentioned that recent troubles with the Institute's instrument were of this type. After thorough cleaning, lubrication, etc., spring pressures would appear normal; however, after even short periods of operation, it was found that the rolls were locked together and high forces were required to separate the rolls.

With the above in mind, two extreme situations were investigated. In the first the pressure roll was blocked in such a manner as to allow only a 0.007-inch separation of the rolls. This would be analogous to the situation where "seizing" takes place, requiring quite high pressures to separate the rolls. In the second situation, the pressure roll was blocked in such a manner that minimum separations of the rolls were 0.010 inch and 0.020 inch; in other words, complete meshing of the rolls was prevented.

Flat-crush results obtained under the above conditions are summarized in Table VII and the associated flute height measurements are tabulated in Table VIII. Referring to the tables, it may be noted that allowing only a 0.007-inch separation between the rolls resulted in about a 4% decrease in Concora results with little or no change in flute height. With regard to the opposite situation, it may be noted that a minimum allowable clearance of 0.010 inch had little or no effect on flat crush. At the 0.020-inch level, however, appreciably higher Concora flat-crush results were obtained while the caliper decreased substantially.

It may be recognized that the above represents an artificial simulation of possible conditions which may affect the instrumental results. On the other hand, if such factors as wear, lubrication, etc., may affect the instrumental operation, their isolation and prevention may be a difficult matter.

TABLE VII

EFFECT OF BLOCKED PRESSURE ROLL ON CONCORA FLAT CRUSH

Clearance, inches		1898	1897	1894	Average	Diff., % [a]
		Concora Flat Crush, p.s.i.				
Control	Trial 1	32.5	39.3	34.5		
	Trial 2	32.5	39.6	35.1		
	Average	32.5	39.4	34.8	35.6	--
0.007-inch Maximum						
	Trial 1	31.3	38.9	33.3		
	Trial 2	31.5	38.2	32.2		
	Average	31.4	38.6	32.7	34.2	-3.9
0.010-inch Minimum						
	Trial 1	32.7	41.5	34.6		
	Trial 2	31.6	39.2	34.4		
	Average	32.2	40.3	34.5	35.7	+0.3
0.020-inch Minimum						
	Trial 1	34.2	45.2	38.7		
	Trial 2	33.1	42.7	36.7		
	Average	33.6	43.9	37.7	38.4	+7.9

[a] Based on control as reference.

TABLE VIII

EFFECT OF BLOCKED PRESSURE ROLL ON FLUTE HEIGHT

Clearance		Flute Height, points 1898	1897	1894	Average	Diff.,% [a]
			End Flute			
Control	Trial 1	199.3	197.8	203.3		
	Trial 2	199.8	204.0	205.5		
	Average	199.6	200.9	204.4	201.6	--
0.007-inch Maximum	Trial 1	204.3	207.0	205.3		
	Trial 2	202.7	207.2	203.3		
	Average	203.4	207.1	204.3	204.9	+1.6
0.010-inch Minimum	Trial 1	197.5	204.2	203.5		
	Trial 2	202.2	202.3	203.7		
	Average	199.8	203.2	203.6	202.2	+0.3
0.020-inch Minimum	Trial 1	187.0	188.5	191.5		
	Trial 2	191.3	195.5	194.0		
	Average	189.2	192.0	193.8	191.7	-4.9
			Center Flute			
Control	Trial 1	189.7	199.5	193.0		
	Trial 2	193.0	196.3	196.3		
	Average	191.4	198.9	194.6	195.0	--
0.007-inch Maximum	Trial 1	196.0	197.8	193.7		
	Trial 2	193.5	195.8	196.8		
	Average	194.2	196.8	195.2	195.4	+0.2
0.010-inch Minimum	Trial 1	186.7	192.2	191.5		
	Trial 2	187.2	190.7	194.8		
	Average	187.0	191.4	193.2	190.5	-2.3
0.020-inch Minimum	Trial 1	179.0	180.7	179.0		
	Trial 2	182.2	182.5	181.5		
	Average	180.6	181.6	180.2	180.8	-7.3
			End Flute			
Control	Trial 1	203.2	209.7	207.2		
	Trial 2	211.0	211.8	208.0		
	Average	207.1	210.8	207.6	208.5	--
0.007-inch Maximum	Trial 1	212.2	208.5	207.7		
	Trial 2	210.8	205.0	205.3		
	Average	211.5	206.8	206.5	208.3	-0.1

TABLE VIII--CONTINUED

EFFECT OF BLOCKED PRESSURE ROLL ON FLUTE HEIGHT

Clearance		Flute Height, points 1898	1897	1894	Average	Diff., % [a]
		End Flute--Continued				
0.010-inch Minimum	Trial 1	198.0	206.8	196.0		
	Trial 2	203.8	207.0	206.8		
	Average	200.9	206.9	201.4	203.1	-2.6
0.020-inch Minimum	Trial 1	187.7	198.2	189.8		
	Trial 2	198.7	200.8	194.3		
	Average	193.2	199.5	192.0	194.9	-6.5

[a] Based on "Control" results as reference.

PART 9. EFFECT OF SPECIMEN WIDTH

A number of phases of this investigation have suggested that flute height and Concora test readings may be related. To further study this phenomena, specimens were fluted having widths of 0.5, 0.375, and 0.260 inches. As the specimen width is reduced, the effective roll pressure should increase in direct proportion to the decreases in specimen width. If it may be assumed that Concora flat crush is directly proportional to specimen width, at least within limits, this procedure may be thought of as a supplement to previous investigations of the effect of roll pressure where the spring force was varied.

The results obtained are summarized in Table IX and graphically illustrated in Figure 10. It may be noted in the table that decreasing the specimen width increased flute height--from 193.9 points at 0.5 inch to 203.1 points at 0.26 inches. Concora flat-crush values decreased from 38.4 p.s.i. at 0.5 inch to 33.0 p.s.i. at 0.26 inches. These results, therefore, appear to be in qualitative agreement with previous phases of this study which have indicated a relationship between flute height and test readings.

PART 10. EFFECT OF TILTING OR COCKING THE DRIVE ROLL

As mentioned previously, uneven pressure across the width of the specimen may be obtained under some conditions. To study this variable, it was suggested that the conditions be simulated by cocking or tilting the drive roll, that is, by raising the back end of the drive roll various amounts while holding the front edge in contact with the hot plate surface.

TABLE IX

EFFECT OF SPECIMEN WIDTH ON CONCORA FLAT CRUSH

	Specimen Width, inches					
	0.5		0.375		0.260	
Flute No.	Average	Range	Average	Range	Average	Range
	Flute Height, points[b]					
1	205.0	19.0	211.4	9.0	209.9	9.0
2	195.2	13.0	198.3	5.5	202.8	7.0
3	193.6	15.5	200.0	5.0	203.6	5.0
4	192.6	16.5	199.4	7.0	203.0	3.5
5	193.8	18.0	201.0	3.5	203.8	6.0
6	191.5	18.0	200.0	6.0	202.8	6.0
7	191.3	14.0	200.6	4.0	202.5	7.0
8	193.2	18.0	202.0	6.5	204.2	5.5
9	199.8	8.0	203.6	5.0	202.2	6.0
10	210.8	24.0	210.8	8.0	207.9	14.5
Average [a]	193.9	15.1	200.6	5.3	203.1	5.8
	Concora Medium Test, p.s.i.					
	38.4 p.s.i.		36.0 p.s.i.		33.0 p.s.i.	

[a] Average flute height based on flute heights for flutes 2 through 9 only.

[b] Averages of 10 specimens.

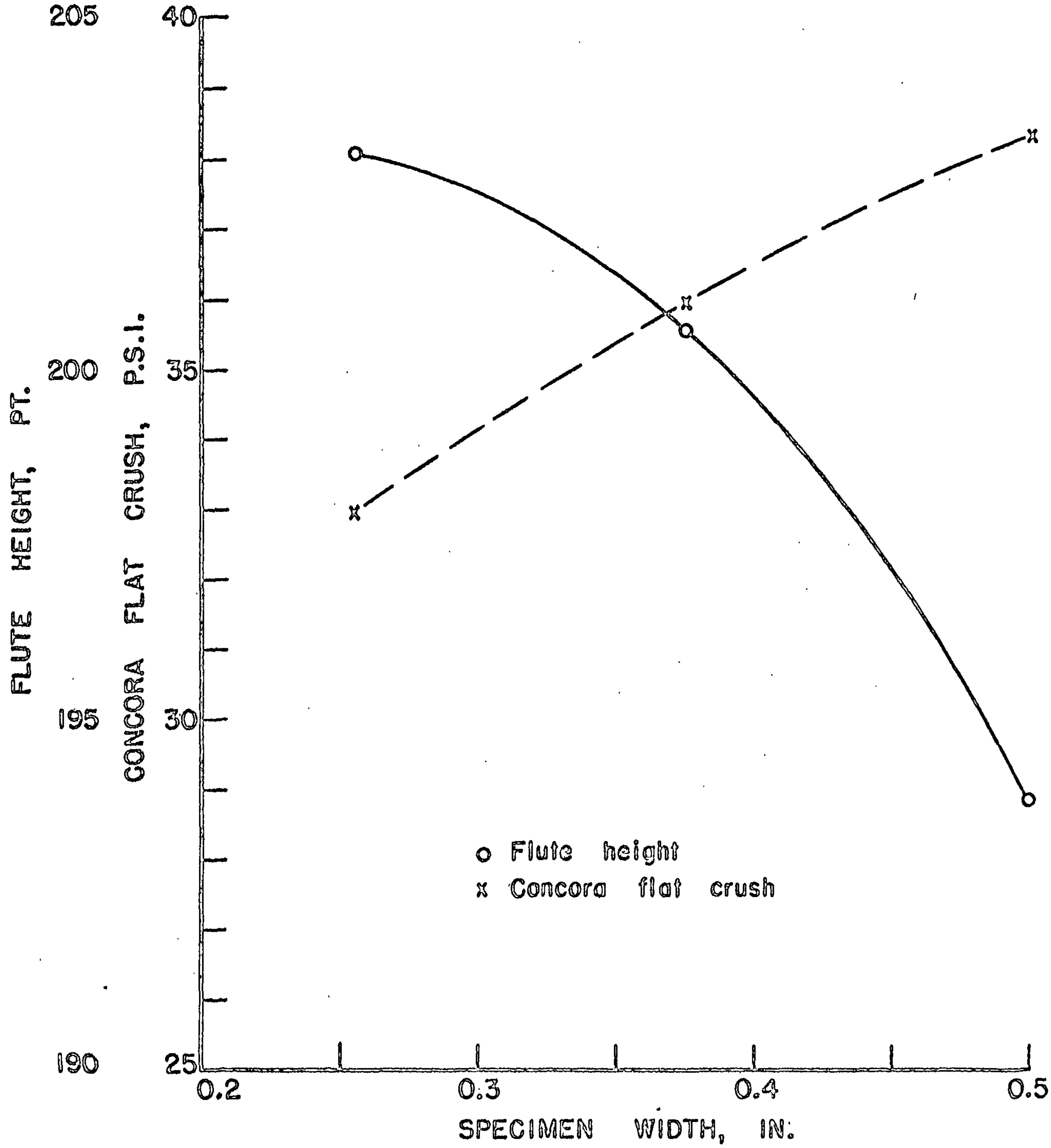


Figure 10. Effect of Specimen Width on Flute Height and Concora Test Readings

Initial trials indicated that the back end of the roll could be raised as much as 0.005 inch and preparations were made to study the effect of an 0.002 and an 0.005-inch tilt of the roll. During the course of the work, it was observed, however, that the 0.005-inch tilt could not be maintained. For that reason, only the information obtained at the 0.002-inch level is summarized herein.

The results obtained are summarized in Table X. As may be noted in the table, cocking the drive roll appeared to produce a slight decrease in the flat-crush results although the results may not be significant. Little or no change in flute height appeared to occur. It may be remarked that the 0.002-inch tilt of the drive roll was hardly sufficient to produce any noticeable change in the pressure pattern. For that reason, additional work in this area may be helpful at some future time.

PART 11. EFFECT OF ROLL TEMPERATURE

The effect of corrugating roll temperature was investigated in the previous instrumentation study. Roll temperature of 149, 235, 310 and 414°F. were used and the following over-all averages were obtained:

Roll Temperature, °F.	Concora Medium Test lb.	Concora Medium Test p.s.i.
149	47.93	28.8
235	52.93	31.8
310	51.48	30.9
414	57.05	34.2

TABLE X

EFFECT OF TILTING OR COCKING THE DRIVE ROLL

		1898	1897	1894	Average	Diff., % [a]
			Flat Crush, p.s.i.			
Control	Trial 1	31.5	41.2	34.2		
	Trial 2	32.0	39.6	33.3		
	Average	31.8	40.4	33.8	35.3	--
Tilted 0.002 inch	Trial 1	30.8	38.5	33.6		
	Trial 2	31.9	40.0	32.6		
	Average	31.4	39.3	33.1	34.6	-2.0
			Flute Height, points End Flute			
Control	Trial 1	202.7	202.8	203.3		
	Trial 2	200.3	205.0	208.8		
	Average	201.5	203.9	206.0	203.8	--
Tilted 0.002 inch	Trial 1	201.0	207.7	206.0		
	Trial 2	200.5	205.0	202.5		
	Average	200.8	206.4	204.2	203.8	0.0
			Center Flute			
Control	Trial 1	195.3	195.5	196.7		
	Trial 2	198.5	194.0	191.2		
	Average	196.9	194.8	194.0	195.2	--
Tilted 0.002 inch	Trial 1	193.8	194.8	198.5		
	Trial 2	196.0	198.2	199.2		
	Average	194.9	196.5	198.8	196.7	+0.8
			End Flute			
Control	Trial 1	205.7	204.7	205.8		
	Trial 2	206.2	204.5	205.8		
	Average	206.0	204.6	205.8	205.5	--
Tilted 0.002 inch	Trial 1	213.2	204.2	204.7		
	Trial 2	205.3	203.2	207.7		
	Average	209.2	203.7	206.2	206.4	+0.4

[a] Based on control as reference.

As may be seen from the above, there appears to be an increase in flat crush with increasing temperature. Taking the temperature extremes, it may be estimated that a temperature tolerance of ± 25°F. may permit Concora test variations of ± 0.5 p.s.i.

While temperature has not been considered a sensitive variable in the operation of the fluter on the basis of the above results, it was thought advisable to check the effect of this variable. For this purpose, the three samples employed in other phases of the study were evaluated using roll temperature of 250, 300, 350, and 400°F. The caliper of the middle flute on each specimen was measured in addition to the flat crush. A tabulation of the results may be found in Table XI. As may be noted in the table in the 300 to 400°F. temperature range, essentially no change in test results were observed and a statistical analysis of the results confirmed the conclusion. Somewhat lower results were obtained at the 250°F. temperature, which analysis indicated were statistically significant.

The data of this study, therefore, appear to be in partial agreement with the previous results in that lowering the temperature below 300°F. yielded lower results. However, in the important temperature range of 300 to 400°F., no significant temperature effect is indicated by the data of this study. No particular reasons for the difference in trends for the two sets of data are known, however; because neither study indicated that temperature exerted any great effect for the normal temperature ranges or tolerances employed, it was felt that additional work was not warranted at this time.

TABLE XI

EFFECT OF ROLL TEMPERATURE ON CONCORA FLAT CRUSH

Roll Temp., °F.	Trial No.	Concora Flat Crush, p.s.i. 1898	1897	1894	Av.	Diff. %[a]	Flute Height, points (Fifth flute) 1898	1897	1894	Av.	Diff., %[a]
250	1	30.3	39.4	32.2			187.1	188.6	194.2		
	2	30.5	38.2	32.8			192.6	190.8	194.5		
	Av.	30.4	38.8	32.5	33.9	-5.0	189.8	189.7	194.4	191.3	- 1.4
300	1	30.8	40.0	34.4			191.8	195.6	194.0		
	2	32.8	40.2	33.6			192.2	196.0	197.5		
	Av.	31.8	40.1	34.0	35.3	-1.2	192.0	195.8	195.8	194.5	+ 0.3
350	1	32.4	39.7	34.1			189.4	196.8	194.8		
	2	33.2	39.8	34.6			191.5	196.8	194.8		
	Av.	32.8	39.8	34.4	35.7	--	190.4	196.8	194.8	194.0	--
400	1	32.7	40.7	33.6			193.8	197.0	197.3		
	2	31.6	39.7	35.0			192.9	197.2	196.7		
	Av.	32.2	40.2	34.3	35.6	-0.3	193.4	197.1	197.0	195.8	+ 0.9

[a] Based on 350°F. results as reference.

PART 12. EFFECT OF A DIFFERENCE IN ROLL TEMPERATURE ON CONCORA TEST RESULTS

As noted in the previous section, if roll temperature has an effect on test readings, its possible influence appears to be reasonably small in terms of the present ± 25°F. specification in temperature. It was thought desirable, however, to make a cursory check of the effect that a difference in temperature between the two rolls might have on flat crush. Some temperature difference between the two rolls is quite normal; however, larger differences might arise from a number of causes such as (1) corrugating roll raised off hot plate or (2) unbalanced or burned out heating elements. For the purpose of this check, the drive roll was raised above the hot plate surface a small amount. The resulting air gap reduced the heat transfer to the drive roll and its temperature decreased to near 300°F. The driven roll temperature was near 350°F., giving a temperature difference of about 50°F.

The results obtained are summarized in Table XII. In the table it may be noted that the unbalance in roll temperature had little or no effect on either the flat crush or flute height. In view of the above, it would seem that the present ± 25°F. specification on roll temperature is probably adequate.

PART 13. RACK AND COMB--COMPARISON OF ORIGINAL AND MODIFIED RACK AND COMB

As mentioned previously, the newer racks supplied by the manufacturer have been modified by cutting about 0.05 inch from the top end surfaces of the rack. In other words, the top surfaces at the ends of the rack lie about 0.05 inch lower than a plane through the flute tips. In the original racks the end top surfaces are of the same height as the flute, lay in the same plane as the flute tips.

TABLE XII

EFFECT OF A DIFFERENCE IN ROLL TEMPERATURE ON CONCORA TEST RESULTS

Roll Temperature Difference		1898	1897	1894	Average	Diff., %
		Concora Flat Crush, p.s.i.				
Control (10°F.)	Trial 1	31.5	41.2	34.2		
	Trial 2	32.0	39.6	33.3		
	Average	31.8	40.4	33.8	35.3	--
50°F.	Trial 1	32.7	38.7	34.3		
	Trial 2	31.5	40.4	33.5		
	Average	32.1	39.5	33.9	35.2	-0.3
		Flute Height, points End Flute				
Control (10°F.)	Trial 1	202.7	202.8	203.3		
	Trial 2	200.3	205.0	208.8		
	Average	201.5	203.9	206.0	203.8	--
50°F.	Trial 1	201.5	207.3	203.2		
	Trial 2	203.5	202.7	206.0		
	Average	202.5	205.0	204.6	204.0	+0.1
		Center Flute				
Control (10°F.)	Trial 1	195.3	195.5	196.8		
	Trial 2	198.5	194.0	199.2		
	Average	197.9	194.8	198.0	196.9	--
50°F.	Trial 1	191.2	196.7	196.3		
	Trial 2	196.5	192.5	196.7		
	Average	193.8	194.6	196.5	195.0	-1.0
		End Flute				
Control (10°F.)	Trial 1	205.7	204.7	205.8		
	Trial 2	206.2	204.5	205.8		
	Average	206.0	204.6	205.8	205.5	--
50°F.	Trial 1	205.0	208.3	213.7		
	Trial 2	205.5	200.7	209.2		
	Average	205.2	204.5	211.4	207.0	+0.7

Based on control as reference.

It is believed this change was made in an attempt to reduce the commonly observed difference in flute height between end and middle flute--- see Part 2 of this report. The difference in flute height appears to occur because the end flutes are distorted in the taping operation. By reducing the height of the end surfaces, it was apparently felt that less distortion of the end flutes would occur. At the same time, the excess flutes formed by the fluter could be safely precrushed so as to leave 10 flutes for test.

It is the latter factor which limits the degree of end relief of the rack when this method is employed. Thus, if the degree of end relief were materially increased, the possibility would exist that the excess flutes would not be fully collapsed and could, therefore, contribute to the test reading. While the present relief of 0.05 inch could probably be safely increased, it may be questioned whether a material improvement in flute height uniformity would result.

A comparison of the "original" and "modified" racks and combs was made using Concora fluter No. 210. As noted in the procedure, alternate specimens from each sample after fluting were formed and taped in the two types of rack and comb. The specimens were subjected to the usual conditioning period and then tested in the order in which they were fluted. In this manner, any changes in fluter, test machine or test atmosphere during the test period could not confound the comparison of the action of the two types of racks.

A summary of the results may be found in Table XIII. As may be noted in the table, in two of the comparisons the modified rack and comb

TABLE XIII

EFFECT OF TYPE OF RACK ON CONCORA FLAT CRUSH

Sample No.	Type of Rack Original	Modified	Diff., %[a]
	Concora Flat Crush, p.s.i.		
1898	33.4	34.0	+1.8
1897	40.0	40.5	+1.2
1894	35.9	35.1	-2.2
	Flute Height (First flute), points		
1898	203.5	199.6	-1.9
1897	206.4	205.7	-0.3
1894	206.0	205.4	-0.3
	Flute Height (Fifth flute), points		
1898	192.9	189.6	-1.7
1897	197.2	195.9	-0.7
1894	195.9	195.7	-0.1
	Flute Height (Tenth flute), points		
1898	205.2	205.1	-0.0
1897	209.4	210.6	+0.6
1894	207.5	210.7	+1.5

[a] Based on "original" as reference.

yielded slightly higher test readings than the original rack and comb. A slightly lower test average was obtained for the third sample. These results were subjected to an analysis of variance with the following results:

Source of Variance	Degree of Freedom	Mean Square	F
Between samples	2	1278.38	147 [a]
Between rack and combs	1	1.10	0.14
Interaction	2	16.70	2.10
Residual	114	7.95	

[a] Significant at 1% level.

The above analysis indicated that the original and modified rack and combs yielded equivalent results. It may also be noted that the flute height measurements in Table II indicate that no significant changes in flute height uniformity were achieved by the use of the modified rack, that is, the difference in flute height between end and middle flute was nearly the same for both types of racks.

Because nonuniform flute height may contribute to the variability of the test and to differences within and between test machines, additional efforts to achieve a more ideal test specimen seemed warranted. Further discussion of this factor may be found in Part 14.

PART 14. RACK AND COMB--PRELIMINARY TRIALS OF MEANS OF ACHIEVING MORE UNIFORM END AND CENTER FLUTE HEIGHTS

In considering means whereby the end-to-middle flute height difference could be reduced, a number of alternatives were considered. For example, the method employed in the present "modified" rack might be employed, trying successively greater end reliefs. It was thought, however, that the chances of success were rather uncertain. A second possibility would be to construct a rack and comb with sufficient flutes to receive the full number of flutes formed by the fluter--the excess number of flutes over 10 could then be cut off or manually collapsed prior to test. If it were desired to maintain the present 10 flute specimen, this procedure would require a specimen length sufficient to form 12 flutes. Under these circumstances, two disadvantages may be seen, namely, (1) all users of the machine would require a new rack and comb, and (2) a 6-inch specimen length might not be sufficient, thereby requiring modification of the die cutters commonly employed to prepare specimens. For these reasons this procedure was ruled out for the present.

It was finally decided that, perhaps, the simplest way in which the influence of the high end flute could be removed would be to either (1) cut them off or (2) manually collapse the two end flutes prior to test. Eight flutes would, therefore, be tested in place of the present ten.

Initially, the assumption was made in comparing eight- and ten-flute specimens that flat crush is linearly related to the number of flutes. This factor was studied in the original instrumentation program in the Concora instrument--see Testing, Compression Report 48, September 3, 1954. In that study, a linear relation between the two factors was found down to about 5 flutes. However, a somewhat different procedure was employed than is suggested here. Thus, in the cited work, 9, 8, 7, etc., flute specimens were obtained by cutting the required number of flutes from one end of the specimen. A high end flute on the other end of the specimen would, therefore, be included among the tested flutes. The previous work continues to lend credence to the assumption of linearity between number of flutes and flat crush. However, the difference in test procedure may produce a second effect. For example, if two specimens identical except that one has a high flute were tested, it may be anticipated that the specimens with flutes of constant height would give a higher test reading since the load-bearing members would act more nearly in unison. Therefore, if a 10-flute specimen with flutes of unequal height is compared with an 8-flute specimen with flutes of more uniform height, the more uniform specimen may be expected to give a higher test value on a unit area or flute basis.

With the above in mind, two trials were made of the suggested procedure of collapsing the end flutes of the specimen prior to test. In the first trial, normal 10-flute specimens were compared against 8-flute specimens prepared by collapsing the two end flutes. In the second trial, the above two types of specimen were prepared as well as 6-flute specimens.

The results are summarized in Table XIV. As may be noted in the table, removal of the end flutes appeared to result in higher test values when expressed on a p.s.i. basis. For two of the samples, namely, 1897 and 1894, the differences were found to be significant at the .05 level when subjected to a "t" test. It may be noted, however, that the 6-flute specimen exhibited even greater increases in test load, thereby casting doubt on the

TABLE XIV

EFFECT OF NUMBER OF FLUTES AND TYPES OF SPECIMEN

ON CONCORA RESULTS

Sample No.	Trial No.	Normal 10-Flute	8-Flute, End Flutes Removed	Diff., % [a]	6-Flute, End Flutes Removed	Diff., % [a]
			Type of Specimen			
			Concora Flat Crush, p.s.i.			
1898	1	32.6	33.3	+2.1	--	--
	2	34.3	35.3	+2.9	36.2	+ 5.5
1897	1	39.8	41.7[b]	+4.8	--	--
	2	41.7	43.8[b]	+5.0	46.3[b]	+11.0
1894	1	34.1	35.7[b]	+4.7	--	--
	2	35.4	36.8[b]	+4.0	39.2[b]	+10.7
			Standard Deviation, p.s.i.			
1898	1	2.22	2.75		--	
	2	2.22	2.65		3.98[b]	
1897	1	2.14	2.58		--	
	2	1.60	2.28		2.33	
1894	1	1.61	2.42[b]		--	
	2	2.05	1.68		1.88	

[a] Based on normal 10-flute specimen as reference.

[b] Significantly greater than normal 10-flute average (or standard deviation) at the .05 level.

initial assumption of a linear relation between flat crush and number of flutes. As a second matter of interest, standard deviations were computed for each condition and are shown in the lower portion of the table. It may be noted that while only two of the standard deviations associated with the 6- or 8-flute specimens were significantly greater than for the 10-flute specimens, the general tendency was for lower standard deviations with the 10-flute specimens. Maltenfort and Long indicate that their results show an increase in test precision as the number of flutes increase (2). The above results would seem to be in qualitative agreement with their work, therefore.

Summarizing briefly, a straightforward comparison of the benefits to be achieved with specimens of more uniform flute height _within_ specimens does not appear to be obtained with the procedures used herein. In particular, the comparisons appear to be confounded by a lack of linearity between flat crush and number of flutes--past evidence to the contrary. With the above in mind, it was thought desirable to conduct a second series of tests employing a somewhat different procedure. In particular, it was thought advisable to hold the number of flutes constant. For this purpose, 8-flute specimens were prepared in two ways--namely, by (1) collapsing the two end flutes and (2) collapsing two of the middle flutes. Six-flute specimens were also similarly prepared. In performing the tests, specimens were tested after the normal conditioning period employed throughout this study and also "immediately" after forming.

The results obtained are summarized in Table XV. As may be noted in the table, somewhat higher test results tended to be achieved with

TABLE XV

EFFECT OF TYPE OF SPECIMEN ON CONCORA FLAT CRUSH

Concora Flat Crush, p.s.i.

	Type of Specimen					
	8 Flutes			6 Flutes		
Sample No.	End Flutes Removed	Center Flutes Removed	Diff., % [a]	End Flutes Removed	Center Flutes Removed	Diff., % [a]
			Conditioned Tests			
1898	35.1	34.5	- 1.7	35.5	35.0	- 1.4
1897	43.4	43.2	- 0.5	44.3	43.2	- 2.5
1894	36.2	34.3	- 5.2	34.9	34.9	0.0
			Unconditioned Tests			
1898	41.0	38.1	- 7.1	40.0	39.0	- 2.5
1897	55.5	54.6	- 1.6	56.2	55.0	- 2.1
1894	43.7	43.3	- 0.9	44.2	43.8	- 0.9

[a] Based arbitrarily on "End flutes removed" as references.

specimens of more uniform flute height, that is, those specimens where the high end flutes were removed. The same basic trend was exhibited by both conditioned and unconditioned tests. The differences were small, however, and with two possible exceptions, it may be doubted whether they are significant. In view of the small differences encountered, it was not thought necessary to perform any extensive analysis of the data; however, such calculations may easily be made if such appears desirable. In any event, at present it is felt that the above results indicate that the high end flutes probably have only a minor effect on either the test load or test precision. It therefore suggests that principal attention should be centered on the problem of reducing differences in flute height between specimens or machines.

PART 15. COMPARISON OF TAPING METHODS

During the course of the investigation, some question arose as to possible differences in results caused by differences in taping procedure. Quoting from the operating instructions supplied with the machine, the following taping procedure was recommended: "When the fluted sample comes out the right side of the machine, it is laid carefully on the corrugated rack so that a portion of the specimen is resting on the flat surface at each end of the rack. The comb is then placed over the fluted sample, so that it is held firmly into the flutes of the rack. A rolling motion of the comb as it is placed on the sample aids in forming the sample onto the rack. While the sample is held firmly in the rack, a 5-inch strip of tape, adhesive side down, is placed on the exposed flute tips and strapped down firmly. The comb is then carefully slipped out of the flutes without damage to the sample. The "single-face" specimen is now carefully lifted straight up from the rack to avoid damaging the flutes."

The procedure used at the Institute is defined below:

a. Place the specimen in the forming die (or rack) taking care that the best side of the specimen is properly oriented.

b. Gently press the comb over the formed specimen and into the grooves of the rack.

c. Apply double-face tape to the exposed surface and press tape and specimen together using the rubber roller device supplied with the machine.

d. Slip the comb out of the flutes and remove the specimen for test.

In comparing the two procedures, it appears that they are identical except that (1) rubber roller is used at the I.P.C. rather than a thumb or finger and (2) the manufacturer's method insists that the specimen be "lifted straight up." At the Institute, operators have been allowed to lift the specimen from the rack by grasping one end.

A trial was made of the two procedures with the results shown in Table XVI. As may be noted in the table, the two methods appeared to yield essentially equal results in terms of both flute height and test load. At present, therefore, the procedures may be considered to yield equivalent results.

TABLE XVI

COMPARISON OF TAPING METHODS

Sample No.	I.P.C. Roller Method	Concora Thumb Method	Diff., % [a]
Concora Flat Crush, p.s.i.			
1898	32.4	32.9	+ 1.5
1897	42.2	42.3	+ 0.2
1894	35.4	34.7	- 2.0
Flute Height, points (First flute)			
1898	208.1	209.5	+ 0.7
1897	212.5	210.5	- 0.9
1894	209.1	209.5	+ 0.2
Flute Height, points (Fifth flute)			
1898	191.0	189.9	- 0.6
1897	196.0	195.0	- 0.5
1894	195.9	197.4	+ 0.8
Flute Height, points (Tenth flute)			
1898	206.9	207.3	+ 0.2
1897	210.2	210.2	0.0
1894	208.0	208.8	0.0

[a] Based arbitrarily on I.P.C. Method.

PART 16. EFFECT OF MOISTURE CONTENT OR TEST ATMOSPHERE

The effects of moisture content on Concora test results may be considered from a number of standpoints. First of all, samples may not be given any particular conditioning prior to fluting. Such a procedure may often be employed in mill-control tests. Two separate investigations of this factor have been made in the past (3,5). In reference 3, specimens were conditioned to equilibrium in atmospheres of 25, 50, and 85% R.H. They were then fluted in the designated atmosphere and tested after a 6-hour conditioning period at 50 ± 2% R.H. The average results obtained are summarized below:

Prefluting Atmosphere Rel. Humidity, %	Concora Flat Crush, p.s.i.	Diff., % [a]
25	31.8	- 0.3
50	31.9	--
85	32.2	+ 0.9

[a] Based on 50% results as reference.

As may be noted, only small differences were encountered and pretest moisture content was considered to have a negligible effect on test results.

In Reference 5 a more extensive series of tests were performed using the same procedures except that an after-fluting conditioning period of 15 and 45 minutes was employed. (Note: This conditioning period had been selected as standard for the medium baseline study.) The average results obtained are summarized below:

Prefluting Atmosphere, Rel. Humidity, %	Concora Flat Crush, p.s.i.	Diff., % [a]
15	31.02	+ 2.4
35	30.60	+ 0.7
50	30.40	--
70	29.67	- 2.4
85	29.61	- 2.6

[a] Based on 50% results as reference.

Reviewing the above, it may be noted that somewhat greater differences were encountered in the second trial with lower results being associated with specimens conditioned to high moisture contents prior to fluting. While the differences were not large, they suggest that pretest moisture content may be a minor variable in the test results if specimens are extremely dry or moist prior to test.

It may be cautioned that the above applies directly to specimens conditioned at 50% R.H. after testing. Where other procedures are employed, such as testing immediately after fluting, greater or lesser effects might be observed.

The above discussion was focussed on the moisture content of the specimens prior to fluting. In the fluting operation, specimens are heated and dried (4). The moisture content drops to a low level--near 0.6% moisture or less--for specimens previously conditioned at 50% R.H. In general, the specimen will be in extreme temperature and moisture unbalance with respect to the test atmosphere. Thus, as the specimen is removed from the fluter, its temperature begins to drop and its moisture content to increase toward equilibrium with the surrounding atmosphere. The rate of moisture regain will depend on the relative humidity in the test atmosphere. For example, if two specimens with identical moisture contents as they emerge from the fluter were exposed to atmospheres of 30% R.H. and 85% R.H., respectively, the specimen in the 85% atmosphere will have a higher moisture content after any time "t" than will the specimen in the 30% R.H. atmosphere.

The absorption of moisture by corrugating medium is a rapid process, see references 4 and 6, therefore the test results obtained will be a function of the relative humidity at time of test even for specimens tested "immediately" after fluting since "immediately" is an indefinite time and actually consists of the time required to remove the specimen from the fluter, apply tape and test.

To illustrate the above remarks, specimens were conditioned to equilibrium at 15, 50, and 85% R.H. They were then fluted and tested in the respective atmospheres using no after-fluting conditioning time, that is, the specimens were tested immediately after fluting. The results obtained are summarized in Table XVII. It may be noted in the table that testing under high humidity conditions produced appreciably lower results than were obtained in the 50% R.H. test atmosphere. At the low test humidity of 15% R.H., the results obtained were near those obtained at 50% R.H. through some trend to obtain higher results might be indicated.

TABLE XVII

EFFECT OF RELATIVE HUMIDITY AT TIME OF TEST ON CONCORA SPECIMENS TESTED IMMEDIATELY AFTER FLUTING

Sample No.	Trial No.	Concora Flat Crush, p.s.i. Rel. Humidity, % 50%	85%	Diff., %[a]	15%	Diff., %[a]
1898	I	40.1	35.5	- 11.5	42.4	+ 5.7
	II	40.8	34.7	- 15.0	41.7	+ 2.2
	Av.	40.4	35.1	- 13.1	42.0	+ 4.0
1897	I	54.6	45.6	- 16.5	56.6	+ 3.7
	II	59.8	38.7	- 35.3	59.4	- 0.7
	Av.	57.2	42.2	- 26.2	58.0	+ 1.4
1894	I	44.9	38.5	- 14.3	46.0	+ 2.4
	II	47.2	36.8	- 22.0	45.6	- 3.4
	Av.	46.0	37.6	- 18.3	45.8	- 0.4

[a] Based on 50% R.H. results as reference.

The above results seem to be in accord with previous remarks regarding moisture regain. While the data are not extensive, they emphasize the need for careful interpretation of test results obtained in unconditioned atmospheres when specimens are tested immediately after fluting.

As mentioned previously, the extreme moisture unbalance of the specimen as it emerges from the fluter results in a rapid pick-up of moisture in the first few minutes of exposure. The original investigation of this facet of the problem indicated that test results decreased rapidly in the first five minutes of exposure and remained sensibly constant for conditioning periods of 10 minutes or longer (4). A later and more extensive study of this factor was reported in Reference 5. A summary of the results is shown below:

Conditioning Time, minutes	Concora Flat Crush, p.s.i.
10	29.25
15	30.43
20	29.89
25	30.47
30	30.40
60	30.57

The above values were based on the averages of 10 samples of corrugating medium (20 specimens tested for each sample) and seem to confirm the results of the previous study; that is, substantially constant results may be obtained if conditioning periods longer than 10 minutes are employed.

In previous pages of this report important deviations in flute height within and between specimens formed on a given fluter were discussed. Such measurements were invariably performed on specimens subjected to the normal conditioning period after fluting of 15 to 45 minutes. While it was not considered likely that such differences could arise as a result of conditioning, the effect of conditioning time on flute height was investigated. For this phase of the study the height of flutes 1, 3, 5, 7 and 10 was measured on 5 specimens from each of the samples after the following conditioning times.

(1) 0.5 minutes (from 20 to 40 seconds were required to complete this measurement).

(2) 15 minutes

(3) 30 minutes

(4) 45 minutes

As may be noted in Table XVIII, a slight increase in flute height appeared to occur during the first 15 minutes, and little or no change appeared to occur in the longer conditioning times. Statistical analysis of the data indicated that the slight increases recorded were not significant statistically in terms of the variation in flute height from specimen to specimen, particularly in the case of the middle flutes. Possibly significant increases in flute height were associated with the end flutes. It may also be noted that the large differences in flute height associated with the end flutes were present immediately after forming, that is, the difference in height between end and center flutes does not appear to arise during conditioning of the specimen.

TABLE XVIII

EFFECT OF CONDITIONING TIME ON FLUTE HEIGHT
Flute Height, points

Flute No.	Conditioning Time, minutes 0.5[b]	15	Diff.[a]	30	Diff.[a]	45	Diff.[a]
Sample No. 1898							
1	200.0	202.1	+2.1	202.0	+2.0	202.6	+2.6
3	192.3	192.8	+0.5	192.9	+0.6	192.6	+0.3
5	193.9	194.6	+1.7	194.1	+0.2	194.3	+0.4
7	195.2	196.0	+0.8	195.9	+0.7	196.3	+1.1
10	205.8	207.9	+2.1	208.1	+2.3	208.5	+2.7
Max. Difference	13.5	15.1		15.1		15.9	
Sample No. 1897							
1	202.9	204.7	+1.8	204.5	+1.6	204.9	+2.0
3	194.8	195.7	+0.9	195.7	+0.9	195.7	+0.9
5	193.8	194.8	+1.0	194.9	+1.1	195.3	+1.5
7	192.4	195.0	+2.6	194.8	+2.4	193.3	+0.9
10	205.1	206.8	+1.7	207.2	+2.1	207.5	+2.4
Max. Difference	12.7	12.0		12.4		14.2	
Sample No. 1894							
1	193.1	194.9	+1.8	194.9	+1.8	194.9	+1.8
3	191.9	192.9	+1.0	192.9	+1.0	192.8	+0.9
5	191.6	192.1	+0.5	192.3	+0.7	192.0	+0.4
7	191.8	192.3	+0.5	192.2	+0.4	192.4	+0.6
10	201.7	203.3	+1.6	203.7	+2.0	203.1	+1.4
Max. Difference	10.1	11.2		11.5		11.1	

[a] Based on 0.5-minute results as reference.

[b] Measurements were complete in from 20 to 40 seconds after forming.

PART 17. RECOMMENDATIONS TO THE MANUFACTURER

As discussed in earlier pages of this report, perhaps the most significant conclusions reached in the study were related to the observed interaction between flute height and test readings. In particular, it appeared that

1. Significant changes in flute height occurred from day to day in specimens formed by the fluter used in this study.

2. Changes in flute height apparently influence test values, i.e., the lower the flute height, the higher the test readings.

It is believed at present that the most logical explanation for these observations lies in variations in the effective roll pressure, because of frictional effects associated with movement of the pressure roll and slider. In other words, it is suggested that the effective roll pressure may vary sufficiently from specimen to specimen and day to day as to significantly imfluence both flute height and test readings. These changes occur despite the fact that no adjustments in spring force were made. As a result, certain modifications in the instrument design appear desirable in order to reduce the fluctuations in flute height and test readings. Because changes in the effective roll pressure most probably originate from erratic change in friction, it is felt that the modifications should involve efforts to reduce or remove the dependence of instrumental performance in sliding friction.

The above findings were transmitted to the manufacturer together with suggestions with regard to means of achieving the desired results. Since that time, a meeting has been held with Messrs. Long and Maltenfort of the Container Corp. on the same subject. The following suggestions are quoted directly from the original letter to Mr. Ascani of the Liberty Engineering Corp. It must be emphasized, however, that they represent only suggestions; other and more efficient means of achieving the desired ends will, no doubt, present themselves to the machine designers.

> "Inevitably work along these lines involves minor or major changes in the instrumental design. Your co-operation in such work would be invaluable. We therefore earnestly solicit your thoughts and recommendations regarding the items mentioned above or the suggestions which follow:
>
> With regard to the slider, the following possible avenues of approach have suggested themselves to us:
>
> 1. Finer finishing and plating of all slider and associated surfaces where rubbing may occur.
>
> 2. Installation of small ball bearings in place of the side dogs of the slider with the bearings on one side riding in a V-groove to constrain motion to one direction.
>
> 3. Installation of small balls with retainers on
>   a. The under surface of the slider at the back (near spring).
>   b. Top forward surface of slider
>   This is quite similar to (2) in that it attempts to replace the present source of sliding friction with rolling friction.
>
> 4. Replacement of entire slider assembly with a spring-loaded roll attached to hot plate. The spring-loaded roll would transmit force to the pressure roll in its plane, thus avoiding imposing a rotational couple on the system.
>
> Only the latter suggestion attempts to remove the rotational couple associated with the present design.
>
> With regard to the pressure roll, the following suggestions have presented themselves:

1. Replacement of present bearings with diagonal contact bearings.

2. Design of new suspension system for the roll to entirely remove it from contacting hot plate.

The latter suggestion is rather indefinite; however, such major changes might required that it is difficult for us to completely specify a proper system.

We realize the aforementioned may appear somewhat revolutionary, Al. However, our recent difficulties have suggested the above approach may be most productive. We shall certainly look forward to hearing your thoughts after you have had a chance to review this latter in terms of your own experiences."

As noted above, considerable stress has been placed on the importance of reducing fluctuations in flute height and the resulting fluctuations in test readings. This has been stressed because, from one standpoint, a laboratory instrument which is intended to simulate the corrugating operation should meet the basic criterion that symmetrically formed flutes of uniform shape and height must be produced. This basic criterion should be met over extended periods of time where the instrument is to be used for quality evaluation or specification.

Achievement of such improvements seem necessary if adequate calibration procedures are to be defined. The Institute of Paper Chemistry will be happy to co-operate in any way it can with all parties concerned to effect the desired improvements.

THE INSTITUTE OF PAPER CHEMISTRY

W. J. Whitsitt, Research Aide
Container Section

R. C. McKee, Chief, Container Section

LITERATURE CITED

1. Long, F. D., and Maltenfort, G. G. A new test for corrugating medium. Fibre Containers 37, no. 12:86, 91-2 (Dec., 1952).

2. Maltenfort, G. G., and Long, F. D. Some aspects of the Concora medium test. Tappi 36, no. 9:88A, 90A, 94-A, 96A (Sept., 1956).

3. The Concora Medium Fluter. Compression Report 48 to the Fourdrinier Kraft Board Institute, Inc., Sept. 3, 1954.

4. Effect of after fluting conditioning time in Concora flat crush. Compression Report 53 to the Fourdrinier Kraft Board Institute, Inc., May 19, 1955.

5. An investigation of variables influencing the test results obtained in pursuance of the continuous evaluation of corrugating medium. Report to the Technical Committee of the Fourdrinier Kraft Board Institute, May, 1956.

6. An investigation of the rate of moisture sorption of paperboard when subjected to sudden changes in atmosphere humidity. Moisture Content, Report 5, March 14, 1956.